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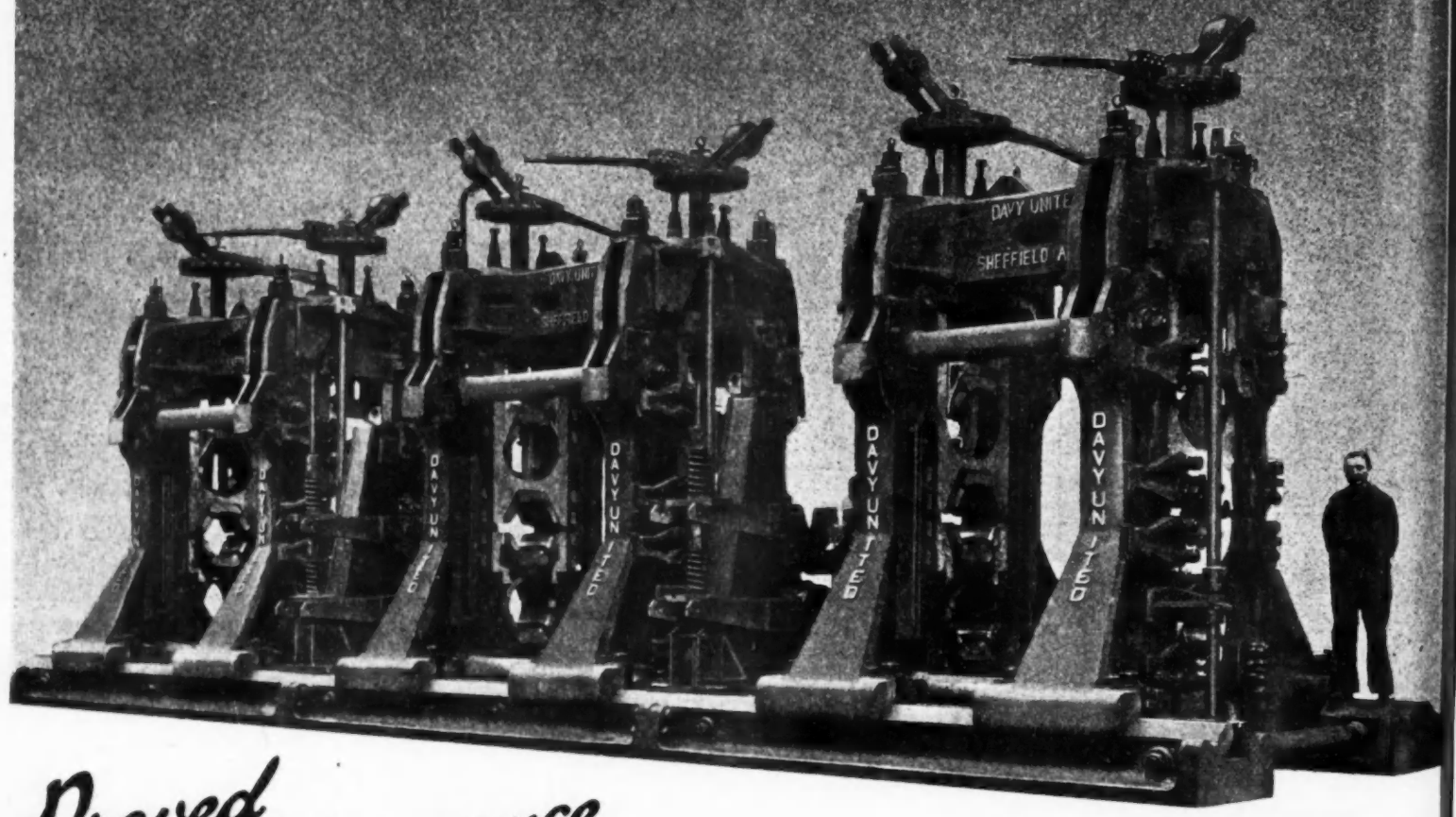

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RECONSTRUCTION OF THE KATUGASTOTA BRIDGE, CEYLON.

THE Katugastota Bridge is situated on the Kandy-Matale Road, in the Central Province of Ceylon, at the point where it crosses the Mahaweli Ganga. It was opened for traffic on March 1, 1860, and the fact that a reconstruction to make it suitable for modern traffic, which was completed in the autumn of last year, embodies the original piers and girders is a tribute both to the excellence of the structure in its first form and to the way in which the reconstruction has been carried out. The road from Kandy to Matale was opened in 1831, the passage across the river being made by ferry. With the growing industry of the country, however, this means of communication began to prove insufficient, and Sir Henry Ward, the Governor, in his address to the Legislative Council in 1858, stated that it was proposed to construct an iron lattice bridge at Katugastota. The span was to be 420 ft., the bridge consisting of three lengths, each of 140 ft. The work was put in hand on September 1, 1858, and, as stated above, it was opened for traffic on March 1, 1860. In view of the plant available at that time, and the up-country situation of the bridge, the construction in this period of 18 months of a 420-ft. structure, which was to last until to-day, suggests both energy and ability in those who were responsible for its construction.

The bridge was built under the supervision of Major Thomas Skinner, the Commissioner of Public Works, who, first employed on the roads of the Colony in 1820 and retiring in 1867, did so much to improve the communications of the Colony. Mr. J. A. Caley, Major Skinner's assistant, superintended the building of the bridge, Mr. W. Lappen being the Clerk of Works. The actual construction was carried out by Mr. J. Robertson and Mudaliyar Welloopillay, of the 4th and 5th Division Pioneers. The names of all these men are commemorated in memorial tablets on the piers of the parapets. The bridge was strengthened in 1904-5, owing to the increasing traffic, and certain other work was carried out in 1926. In the year 1935, however, by which time motor-lorry and 'bus traffic had become heavy, the question of reconstruction was again raised. It was suggested at that time that a new bridge might be necessary, but Mr. S. Mahadeva, M.Inst.C.E., Chief Engineer (Designs) of the Public Works Department of Ceylon, by a careful examination of the condition of the bridge, and a consideration of its history, was able to work out a method of reconstruction which has again brought the bridge up to the standard demanded by the traffic and at a cost of Rs. 180,000.00, as compared with the estimate of Rs. 540,000.00 for a new bridge. The details of the work are described in an interesting paper presented to the Engineering Association of Ceylon by Mr. Mahadeva last year. The information on which this article is based was obtained from that paper. For the various photographs of the bridge which we are able to publish we are indebted to Mr. Mahadeva.

The original bridge consisted of three clear spans, with two masonry piers, each 14 ft. wide at the top. These piers, which are still in use, can be seen in the view of the reconstructed bridge given in Fig. 1, on this page. The lattice girders were double-interlaced Warren girders, and were supplied by Messrs. R. Brotherhood, of Railway Works, Chippenham, Wiltshire. They had heavy bars of uniform section for almost all the shear members, irrespective of the stresses they had to bear. The cross-girders were attached to vertical stiffening members at a level of one-third of the height from the bottom of the main girders. The cross-members were fish-bellied plate girders, the camber of the timber decking across the roadway being formed on the upper side of the web of the cross-girder. The panel points of the lattice girders were at 4-ft. centres.

The main girders were stiffened across the width by 1¼-in. diameter rods below the roadway, and were also braced in between. This old ironwork is now in remarkably good condition. It has had no special paint or protecting medium, being covered with pitch tar so heavily painted over, year after year, that some members have a coat of paint ⅛ in. thick. One of these old girders is well shown in the view of the Kandy end of the bridge during the recent reconstruction which is given in Figs. 4 and 5, on Plate XIV. The original masonry pier referred to above is the second pier in these figures. The one nearest the bank, which is in course of strengthening and enlarging, did not exist in the original bridge. The girder and pier are best seen in Fig. 5.

In 1904 some apprehension began to be felt about the condition of the bridge. There was no record of the load which had been allowed for in the original design, but the increase in heavy cart traffic was seriously overstressing the bridge. A report made in February, 1904, by the Factory Engineer, Mr. E. C. Davies, stated that the compression bars over the piers and abutments were buckled. Although there was no appreciable deflection when a string of five fully-loaded carts, weighing about 40 cwt., passed over the bridge, there was considerable lateral movement. There were no expansion rollers, the bearings being about 4 ft. long, and Mr. Davies considered that this probably caused undue stresses in the end-bay diagonals. A census was taken in June, 1904, and it was found that during a day of heavy traffic 94 bullock carts, 45 carriages of various types and rickshaws, 39 oxen and horses, 5 bicycles, and 6,525 pedestrians passed over the bridge. It was decided that it should be strengthened, and until this work was completed, it was enacted that not more than three carriages or carts, or 50 pedestrians, should pass over the bridge at the same time, that all traffic should proceed at walking pace, and that vehicles should not stop on the bridge nor crowds of persons congregate. The passage of elephants over the bridge was prohibited.

As it would have been very costly to strengthen the bridge, retaining the original clear span, it was decided to erect intermediate piers on each side of the original masonry piers, thus reducing the span to 65 ft. and giving a bridge of six spans instead of three. The new piers which were built each consisted of two concrete cylinders, 7 ft. in diameter to a height of about 10 ft. above ordinary water level, and 6 ft. in diameter above. The piers constructed in this way can be seen in Figs. 7 to 9, on Plate XIV. The cylinders had concrete hearting with steel joists in the centre extending for the full depth. The joists were connected by cleats to three transverse beams, made from 12 in. by 6 in. joists, which carried steel flood plates between the cylinders, as shown in Figs. 4, 7 and 8. The tops of the cylinders were tied together by 16-in. by 6-in. steel joists. The cylinders are stated to have been carried down to the same rock bed as the old main piers. In strengthening the steel work, the compression bars at the ends of the spans were duplicated by bars ranging from 4 in. by ¾ in. to 3 in. by ⅝ in., 1½ in. and 1 in. diameter bolts being provided for the joints. New 15-in. by ⅝-in. and 15-in. by ¾-in. horizontal plates were added to the booms. The new diagonal braces were introduced by disconnecting the lower rivets of the original bars and slewing the bars sufficiently to allow the new bars to be connected alongside of them. Although this slightly altered the inclination of the original bars, the centre lines of the new bars retained the original alignment. The duplicate bars can be seen at the shore end of span in Fig. 5. This strengthening work, which was estimated to cost Rs. 30,792.00, and was completed in 1905, extended the service of the bridge up to the present reconstruction, but made it safe only for 3-ton traffic. The original timber decking remained satisfactory.

Further work had to be done on the bridge in 1915. As a result of floods in 1913, it was found that the river bed had been scoured at rock level at the piers and that the cylinder foundations were in danger. It was accordingly decided to enclose the cylinders with sheet-pile cofferdams, and to repair the mass concrete footing that connected the cylinders at rock level. This work was estimated to cost Rs. 14,000.00. The maintenance of the timber platform of the bridge was at that time also beginning to prove a heavy charge. From 1908 to 1915, Rs. 7,778.00 were spent on the maintenance of the bridge. Large sums were also spent on

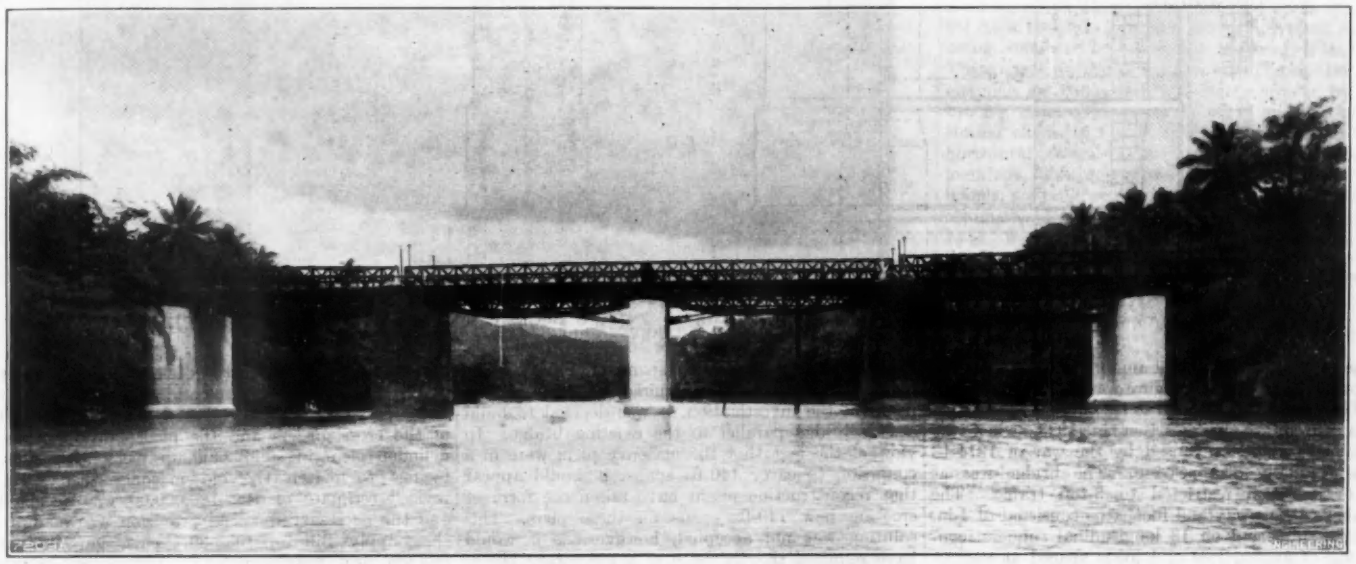
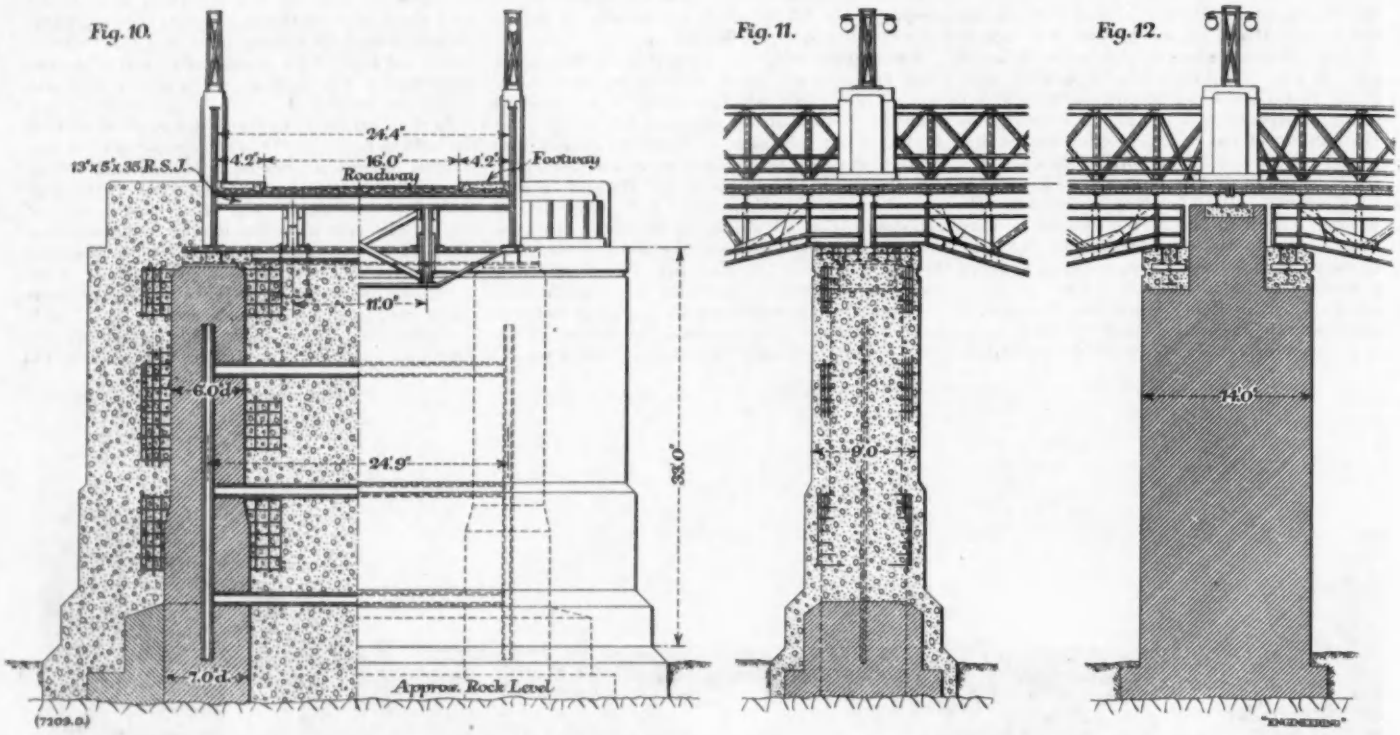


FIG. 1. THE RECONSTRUCTED BRIDGE.

RECONSTRUCTION OF THE KATUGASTOTA BRIDGE, CEYLON.



general repairs. The total amount is not accurately known, but in 1916 the figure was Rs. 8,000.00.

The proposals which led to the present reconstruction appear to have arisen in 1923, when the financial stringency caused by the war of 1914-18 was gradually disappearing. The bridge was at that time still restricted to 3-ton traffic. The timber carriageway and footpaths consisted of 4-in. planks supported on 13 longitudinal runners, consisting of angles, tees and joists spaced at various intervals across the full width of the cross-girders of 23 ft. 11½ in. The girders were 12 in. deep at the centre and 8 in. at the ends, the flanges, 5 in. wide, consisting of two angles riveted to a web plate. The girders and steelwork supporting the decking were much corroded, and it was accordingly decided to replace them at an estimated cost of Rs. 27,200.00. The work was done without stopping the traffic by providing portable wooden ramps of short length to pass traffic over sections where the decking was removed. After the completion of this work in 1926, the bridge was subjected to tests in the course of which it was found that a 4-ton lorry travelling at 4 miles an hour produced a deflection of $\frac{1}{8}$ in. at the centre of the span. At 8 miles an hour, the deflection was $\frac{3}{8}$ in. Two lorries of 4-ton gross load, travelling in the same direction at 4 miles an hour, produced a deflection of $\frac{3}{8}$ in. at the centre, and, at 8 miles an hour, one of $\frac{1}{8}$ in. The same deflection was produced when the same lorries, travelling in opposite directions at 6 miles an hour, met at the centre of the span. Mr. J. Gray, the Factory Engineer at that time, who carried out these tests, stated that the bridge was resilient and that there was no permanent set.

The completion of this work did not meet the full requirements of the situation, and there was an extensive public demand for the reconstruction of the bridge to make it suitable for 6-ton vehicles. In view of this, investigations directed to that end were begun in the latter part of 1927. A census taken in 1928 showed that the average daily vehicular traffic amounted to 953 motor cars and cycles, 277 'buses and lorries, 487 bullock carts and 33 other vehicles. A comparison of these figures with those of the count made in 1904 clearly illustrates the greatly increased demand on the service of the bridge which had grown up in 24 years. The investigations showed that the old masonry piers and abutments were in very good condition, and it was suggested that they were capable of carrying single spans of 140 ft. The cylinder piers, however, required attention. As a result of the investigation, it was decided to build a new bridge parallel to the existing bridge. In view of the fact that the masonry piers were in a condition to carry 140-ft. spans, it would appear that reconstruction might have taken the form of erecting new 140-ft. spans on these piers. This solution was not accepted, however, as it would have required the provision of a temporary bridge during the reconstruction period, and the cost of this with its approaches would have almost equalled the cost of the piers and abutments for a new bridge. Estimates for the new bridge, which was to consist of five 75-ft. spans, were completed in March, 1930, and placed the cost at Rs. 540,000.00. The bridge was to have an 18-ft. roadway, with 6-ft. footways outside the main girders. In spite of the continued pressure from public bodies for the reconstruction of the bridge, nothing was done with this scheme owing to the financial depression which had set in at the time it was brought forward.

When Mr. Mahadeva was appointed to his present position in 1932, the question of the reconstruction was revived. A re-examination of the whole subject, and a consideration of the history of the bridge, showed that a new structure was not imperative and that the destruction of the old piers and abutments and scrapping of the old girders could be avoided. In connection with this aspect of the matter, it may be noted that the sum of Rs. 14,000.00 for the destructive removal of the old bridge was allowed for in the Rs. 540,000.00 estimate for the new bridge. Mr. Mahadeva accordingly prepared a scheme for the reconstruction of the old bridge, at an approximate cost of Rs. 110,000.00. The scheme provided for retaining the old abutments, parapets, approaches and stone masonry piers; retaining the cylinder piers and strengthening the bases; providing a heavy cross beam on the top of the cylinder piers; placing two shallow-depth main girders under the bridge, so as to act as a direct support for the existing cross girders; renewing the decking, and providing a tarmac roadway. This proposal was received with favour, but it was suggested that it was impracticable without the provision of a temporary bridge. Matters were then carried further by careful measurements of the old structure. These showed that the old cylinders were not in good alignment, while, as a result of further examination, it was found that the cross girders were hardly worth retaining. As a result of this work, detailed plans and a revised estimate were prepared. These allowed for the renewal of the cross girders and the incorporation of the cylinder piers in solid built-up piers with stone facings to match the old masonry piers. The revised estimate of Rs. 180,000.00 was accepted and the necessary financial provision was made in the Supply Bill for 1935-36. This sum did not include any provision for a temporary bridge, which it had been suggested would be necessary; the method of working adopted allowed the bridge to remain open to traffic during the period of reconstruction.

Drawings of the reconstructed bridge are given in Figs. 2 and 3, on Plate XIV, and the erection of the first span of the new girder below the old main girder is shown in Fig. 6. The original carriageway width of 16 ft., with 4-ft. footpaths on each side, has been retained, but the revised structure is strong enough to carry subsidiary footways on light girders, outside the main girders, and supported on extensions of the cross girders. This arrangement, if adopted later, would give a 24-ft. wide roadway. The bridge is now suitable for a live load equal to the Ministry of Transport British Standard Loading, that is, a traction engine of 20¼ tons and trailers with axle loads of 6¾ tons at 10-ft. centres. The total load on each new main girder is equivalent to a uniformly distributed load of 143 tons, including 40 per cent. for impact. The footways are designed to take 100 lb. per square foot over the entire bridge, no allowance being made for impact. The working stresses provided for are 7 tons per square inch in tension; a maximum of 6·8 tons per square inch in compression; and shear, in the webs of plate girders, of 5 tons per square inch. The bearing stress on rivets is 10 tons per square inch and the shear stress 5 tons per square inch. In connection with the computation of the strength of the bridge, one of the iron shear members of one of the original girders was removed and replaced by a mild-steel member of equivalent section. Test pieces cut from the old member were pulled at the Technical School, Colombo, and showed a yield point at 14·1 tons per square inch, a maximum tensile stress of 21·95 tons per square inch, and an elongation of 24 per cent.

The work of reconstruction was put in hand in the latter part of 1935, but work was much hampered by unfavourable weather, and flood conditions. The

RECONSTRUCTION OF KATUGASTOTA BRIDGE, CEYLON.

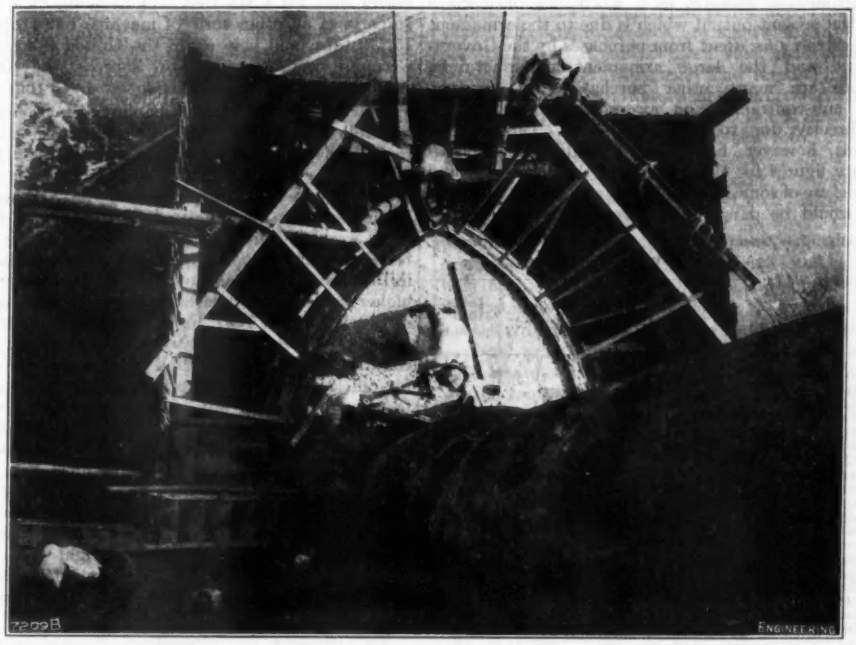


FIG. 13. NEW CONCRETE PIER FOUNDATION.

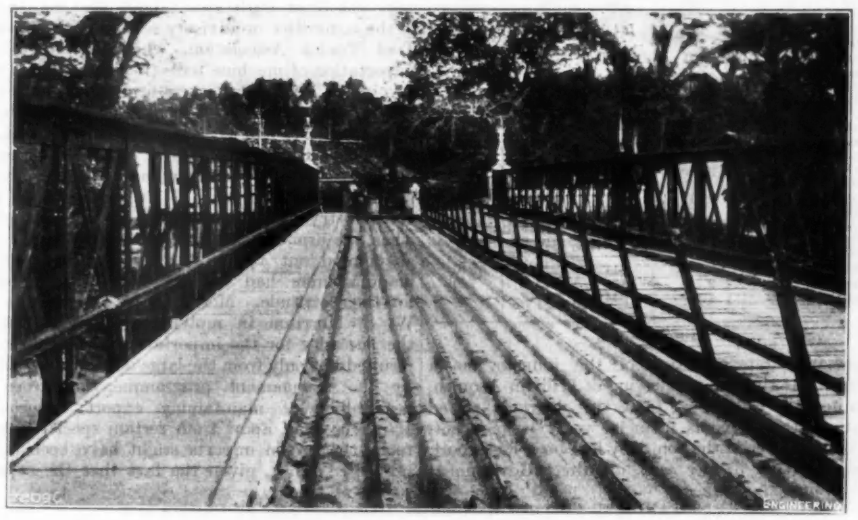


FIG. 14. NEW DECKING IN PROGRESS.

concrete base of the cylinder foundations was approximately 37 ft. by 10 ft., and it was decided to provide a cofferdam of sheet-steel piling round them to permit of their examination and strengthening. The dam provided a working space 58 ft. by 20 ft. Owing to the shallow depth of sand and the irregular and sloping nature of the rock bed, difficulty was experienced in driving the piles. After certain lengths were completed, cross-piling was put in, to divide the cofferdam into compartments, and excavation was begun. It was found that the sheet-steel piling did not make a watertight joint at the base, and, even with sandbags, difficulty was experienced in keeping the water and sand out. Timber sheet piling was used for the remainder of the work, and an inner cofferdam of timber sheet piling was driven 18 in. from the steel piling, the intervening space being filled in with clay. This method had the desired result, but, in addition to the difficulties due to the weather, the contractor failed during the progress of the work, and absconded. Much time was lost in trying to find him before it was possible to take over and re-start the work. One of the cofferdams is well shown in Fig. 9.

The reconstructed piers were designed to rectify the discrepancies between the old piers and the abutments. They have wide, stepped bases of 4 : 2 : 1 concrete enveloping the old bases and founded on dressed faces of the bed rock. They are 16 ft. 4 in. wide, stepped-up in two offsets to 10 ft., and conform as nearly as possible to the shape of the old piers. The outer face is formed with wedged and dressed stone masonry set in cement mortar. Bonding reinforcement between the new and old work was provided by vertical $\frac{3}{4}$-in. mild-steel rods spaced at 12-in. centres round the cylinders and by horizontal rods of the same diameter, also spaced at 12-in. centres. The arrangement is indicated in the drawings of the reconstructed pier which are reproduced in Figs. 10 and 11, on page 270. This arrangement of bonding was adopted in order to obviate the necessity of breaking into the old cylinders, which had steel frames inserted in the hearting. The holding-down bolts of the old main girders were also embedded in the old concrete. The diaphragm plates between the cylinders, seen in Figs. 4 and 7, had no function and tended to separate the concrete filling and prevent homogeneity. They were accordingly removed. The cross-beams stiffening the cylinders, however, were left in place. Two stages in the building of the masonry facing is shown in Figs. 5 and 6, and a view looking down on the new concrete foundation of one of the piers is given in Fig. 13, herewith.

The new main steel under-girders are 64 ft. long overall, and approximately 6 ft. $4\frac{1}{2}$ in. overall in depth. The effective depth between the centres of gravity of the booms is 5 ft. 6 in. At the ends, the girders are 3 ft. $3\frac{1}{2}$ in. deep overall. The depth was made as small as possible in order to keep clear of highest flood level; the depth adopted allows a clearance of 1 ft. 10 in. above the level of 1913. The general arrangement of the girders will be seen from the elevation of the bridge given in Fig. 2. They are divided into five large panels and two small end panels. A departure from the ordinary Warren-girder form has been made by the introduction of vertical members. The lower tension boom is built up of two 12 in. by $3\frac{1}{2}$ in. by 29·23 lb. channels set back to back, 6 in. apart, the individual lengths being connected by vertical cover plates, $\frac{11}{16}$ in. thick. There are no horizontal cover plates, but the channels are connected by a lacing of 2 in. by $\frac{1}{4}$ in. bracing flats. The upper boom is built up of two similar channels, but in this case both vertical and horizontal cover plates are used. The vertical members, nesting between the channels of the booms, are built up of two 6-in. by 3-in. by 12·41-lb. channels. Each diagonal consists of four 3-in. by $2\frac{1}{2}$-in. by $\frac{3}{8}$-in. angles. The girders have a full bearing 2 ft. 3 in. long, and are supported on $2\frac{1}{2}$-in. thick cast-iron bed plates, 3 ft. wide and 2 ft. 3 in. long. These are held down by $1\frac{1}{4}$-in. diameter bolts, 3 ft. long, with distance plates 3 ft. by 8 in. by $\frac{1}{2}$ in. at the lower ends.

The joints in the girders were so arranged as to permit fabricated lengths to be sent to the site and lifted and riveted in position from below the road decking. As the girders are placed at 11-ft. centres, cross bracings of 6 in. by 3 in. by 12·41 lb. channels were provided both horizontally and diagonally. The outer existing girders were also supported by bracing them to the new girders, so that there should be no sway or swing when fast heavy traffic passed over the bridge. These arrangements are shown in the cross-section, Fig. 10. The cast-iron bed plates were supported directly on a grillage which, in the case of the new piers, was made up of 12 in. by 5 in. by 30 lb. joists; on the old piers, these grillages were made from 15 in. by 6 in. by 45 lb., and 7 in. by $3\frac{1}{2}$ in. by 15 lb., joists. These arrangements are shown in Figs. 11 and 12. The shallow depth of the ends of the girders minimised the amount of cutting away necessary on the old piers. The extent of this is shown in Fig. 12. The old masonry was found to be excellent in quality and had clearly been laid with great skill. The cross girders, which support a corrugated-iron decking, are 13 in. by 5 in. by 35 lb. joists. Each main girder is 64 ft. long and weighs 18 tons, and the weight of the 13 cross girders is 5 tons. The corrugated decking, covering the entire width of the carriageway and footpaths, weighs $9\frac{1}{2}$ tons. The total weight of new steelwork in each of the 60-ft. spans is 50 tons, inclusive of the bracing.

The new work was erected by the Government Factory, the method adopted allowing the new material to be erected, span by span, without interfering with traffic on the old timber decking. The staging used for one span was removed for the next; although this entailed a somewhat longer time in construction, it had the advantage of economy. The staging, which can be seen in position during the erection of the first span in Fig. 6, consisted of two trestles, the stanchions of which were 16 in. by 6 in. joists, 36 ft. long, driven into the sand of the river bed to rock level. The stanchions were connected by cross members, as shown. The 16 in. by 6 in. joists supported on the gusset brackets of the stanchions carried longitudinal joists of the same size and of a length to cover the full span of 55 ft. $4\frac{1}{2}$ in. They had temporary bearings on the piers. These runner joists carried the timber working platform on 6 in. by 4 in. wooden cross bearers. A clearance of 2 ft. was provided between the platform and the main girders to permit the necessary riveting to be carried out.

After the new main girders had been erected, the new cross girders were placed in position. There was little clearance between the underside of the timber decking and these new girders, and the old cross girders were in the position in which the new girders were to be fixed. As a result of this, and in order to renew the cross girders without stopping the traffic, it was decided to lift the old main girders and decking. This was done by means of four 25-ton jacks, the steelwork being raised for a height of 10 in. throughout its length. Ramps were provided to enable the traffic to pass over the raised part of the deck. The new cross girders were then placed in position and, with half the width of the roadway closed, the steel decking for the other half was laid. After the decking was riveted in position, the footpath concrete was laid and the granite kerbs fixed. The road concreting was then completed. A view of the deck of the bridge, showing one of the raised spans when half the roadway was nearing completion, is given in Fig. 14, on page 271. The traffic was then passed to the reconstructed side of the carriageway and the other half was dealt with in the same manner. The span was then lowered to position. This operation was carried out on all six spans with complete success. All lifting of the riveted booms of the main girders, cross girders, etc., was carried out from the roadway with tackle and a hand winch. No cranes were used.

The organisation of the labour, plant, materials and stores at the bridge works was in charge of the Government Factory. The work was commenced during the office of Mr. P. G. Macfarlane, A.M.I. Mech.E., and was completed under that of Mr. G. C. Oram, A.M.I.Mech.E., the present Factory Engineer, Mr. C. N. Caldera acting as his assistant.

THE ENGINEERING OUTLOOK.

VIII.—Machine Tools.

The past year saw a further substantial advance in activity in the machine-tool industry, in spite of the fact that the output in 1938 was probably a record at that time. In the years immediately preceding the start of the rearmament programme, many firms in the industry went through a difficult period, which impaired their ability to expand productive capacity when an urgent demand developed for their products. Moreover, in the early stages, manufacturers were probably reluctant to undertake important plant extensions in view of the fact that the machine-tool industry suffers probably more than any other from alternating periods of boom and slump, and a justifiable anxiety was felt regarding the future if the armament programme should be abandoned. Nevertheless, the period since the beginning of rearmament, and particularly the last two years, have seen a very substantial increase in both output and productive capacity and the industry is beginning to approach the position which it should occupy in view of its importance as the basis of practically all branches of engineering manufacture.

During the last three years, in spite of its preoccupation with urgent home orders, the industry has considerably improved its position in export markets and it is to be hoped that the present prosperity will enable it to take full advantage of the increased scale of production, and the associated benefits of cost reduction and extension of the range of products, in order to improve still further its position in export markets. For the duration of the war, a high proportion of the output must be taken for war purposes and although, as argued in this series last year, there is probably developing a considerable deferred replacement demand on the part of civil industry generally, it must not be overlooked that engineering firms which are not normally armament producers will be able, at the end of the war, to utilise many of the modern machine tools, now used for armament production, to meet the requirements of their normal work. If, therefore, a high level of machine-tool production is to be maintained in this country after the war—and there can be no doubt about the vital importance of such a policy—British manufacturers must be in a position to supply substantially the whole of the home market and also to increase considerably their share of international trade.

It is extremely difficult to estimate, for the machine-tool industry as a whole, the proportion of the present output which is due to the armament industries; as, apart from purchases by the Government and the large armament manufacturers, there are many other purchases—for example, by sub-contractors on aircraft work—which are indirectly due to armament work. One or two firms, however, have recently published approximate figures for the division of their turnover and these are of some interest in this connection, although it would be dangerous to assume that they were necessarily representative of the industry as a whole. At the annual meeting of William Asquith, Limited, in December, 1939, the chairman stated that, in the previous financial year, 47 per cent. of the turnover of the company had been for export, and a further 37 per cent. on direct Government work. Earlier in the year, however, the chairman of the Scottish Machine Tool Corporation stated that, of the orders on hand on May 15, only 13·8 per cent. could be directly attributable to armament work.

In spite of the expansion in the output of machine tools in 1939, the increase in the rate of rearmament necessitated a substantial rise in imports, which had fallen considerably in 1938 from the peak level of the previous year. In the first eight months of 1939, imports totalled 19,906 tons, valued at 4,593,000*l.*, against 15,764 tons, valued at 3,257,000*l.*, in the corresponding period of 1938, and 22,489 tons, valued at 4,330,000*l.*, in the first eight months of 1937. Of the total in 1939, 4,127 tons, valued at 1,143,000*l.*, consisted of lathes, of which the United States supplied 1,811 tons and Germany 933 tons. Imports of all other sorts of machine tools totalled 15,779 tons, and here again the United States and Germany were the principal sources, the former supplying 8,358 tons and the latter 4,943 tons.

Table I.—*Machine Tools: United Kingdom Retained Imports.*

—	Volume. Tons.	Index. (1913 = 100.)	Value per ton.	Index. (1913 = 100.)
			£	
1913	312	100	91	100
1931—				
1st Qr.	493	158	164	180
2nd ,, ...	1,167	374	124	136
3rd ,, ...	773	247	146	160
4th ,, ...	1,062	340	167	184
1932—				
1st Qr.	523	167	209	230
2nd ,, ...	276	88	210	231
3rd ,, ...	391	125	142	156
4th ,, ...	294	94	299	329
1933—				
1st Qr.	282	90	219·0	241
2nd ,, ...	236	76	228·0	251
3rd ,, ...	251	80	255·6	281
4th ,, ...	304	97	295·6	325
1934*—				
1st Qr.	441	141	228·8	251
2nd ,, ...	532	171	208·8	229
3rd ,, ...	619	198	204·0	224
4th ,, ...	597	191	223·5	246
1935*—				
1st Qr.	535	172	231·9	255
2nd ,, ...	666	213	201·3	221
3rd ,, ...	634	203	223·6	246
4th ,, ...	734	245	225·1	247
1936*—				
1st Qr.	1,147	367	198·5	218
2nd ,, ...	1,532	481	174·1	192
3rd ,, ...	1,637	525	182·0	200
4th ,, ...	2,322	745	175·0	192
1937*—				
1st Qr.	2,810	901	179·5	197
2nd ,, ...	2,889	926	190·8	210
3rd ,, ...	2,640	846	213·2	234
4th ,, ...	2,188	701	306·5	227
1938*—				
1st Qr.	2,719	871	177·8	195
2nd ,, ...	1,879	602	196·3	216
3rd ,, ...	1,680	538	218·9	195
4th ,, ...	2,002	640	216·8	217
1939*—				
1st Qr.	2,167	644	223·3	246
2nd ,, ...	2,711	869	208·0	229
3rd ,, ...	2,635	844	274·2	301

* Gross imports.

Quarterly imports of machine tools are shown in Table I, herewith, and it will be seen that these rose sharply in the second quarter of 1939 to a figure only slightly below the peak level attained in the first and second quarters of 1937. Whereas, however, in the first and second quarters of 1937, there was little difference in average value per ton between machine tools imported and those exported, in 1939 the average value of imports was considerably higher than that of exports. A possible explanation of this is that, in 1937, imports consisted mainly of tools of types normally manufactured in this country, which were imported owing to the necessity for quick delivery and the fact that British manufacturers were already fully employed; while imports in 1939 may have consisted mainly of special types of machines, not normally produced in this country. That the average value of imports should be higher than that of exports is usually the case, of course, and is due partly to the explanation given above and partly to the fact that the average import values include freight from the country of manufacture, while freight must be added to the average export value to obtain the price paid by the purchaser.

The necessity for importation of machine tools on such a large scale has received a good deal of attention during the past year and, in May, questions were asked in Parliament about the composition of the committee or advisory section of the Machine Tool Trades Association, which agreed to the importation of machine tools (it was suggested that two of the leading importers of machine tools were also leading members of the Association): as to why the needs had not been met in this country, and why national factories were not being established to manufacture machine tools. As events have turned out, it may be argued, perhaps, that the industry was somewhat slow to expand capacity when the armament demand first developed; but, as pointed out above, it must be admitted that manufacturers had a good deal of justification for their attitude. Moreover, as observed by Mr. W. S. Morrison in replying to these questions, the necessity for the importation of machine tools resulted not only from the large demands occasioned by the rearmament programme, but from the desirability of maintaining export connections. It is true that, apart from certain special types of tools, the rise in imports might have been largely prevented: but, given the fact that the capacity of the industry was not sufficient to meet both the increased home demand and to maintain exports, it was undoubtedly preferable to resort to the policy of increasing imports.

On the question of the establishment of national factories for machine tools, Mr. Morrison replied that, in view of the time required for constructing and equipping them, the carrying out of the programme would not be materially assisted by this means. This argument certainly has more justification in the case of machine tools than in certain other cases in which it has been put forward, since the tools are required as quickly as possible and the

TABLE II.—British Exports of Machine Tools by Classes.

—	Tons.				Value (£000.)			
	1937.	1938.	1938 (Jan.-Aug.).	1939 (Jan.-Aug.).	1937.	1938.	1938 (Jan.-Aug.).	1939 (Jan.-Aug.).
Boring mills	893	1,672	777	1,290	110	235	116	171
Drilling machines	1,469	2,534	1,637	1,664	237	445	274	280
Grinding machines	1,393	2,788	1,612	1,810	296	733	410	449
Lathes	3,816	6,734	3,904	6,568	710	1,446	856	1,350
Milling machines	558	1,798	984	1,652	140	424	216	437
Planing and shaping machines ..	874	3,546	1,519	3,563	110	421	194	387
Presses, punching and shearing machines	719	1,445	858	2,288	70	140	88	185
Other sorts	2,175	3,650	2,269	3,313	479	632	395	455
Total	11,897	24,167	13,560	22,148	2,152	4,476	2,549	3,714

actual business of armament production cannot begin until they have been obtained. Nevertheless, if the erection of national factories on the lines of the shadow aircraft factories had been put in hand, say, in 1936, there would have been no need to spend some 4½ million pounds on imports in the first eight months of 1939, nor would the British engineering industry as a whole have been faced, on the outbreak of war, with the immediate cutting off of one of the most important of its sources of supplies of machine tools. It may be noted that in November, 1939, the Machine-Tool Controller of the Ministry of Supply said that assistance was being afforded to various firms to increase the output of tools, and new capacity was being found in the field of concerns not already making machine tools, such as textile-machinery and printing-machine makers. He added that resources were also being established for the manufacture of tools hitherto imported. He found it necessary, however, to appeal to small firms which believed they could make machine tools but had not, so far, received contracts, to try to get in touch with some main contractor under whose wing they could work. He added that he wanted to hear of every idle machine tool in the country capable of being put to war work, as work was available for all of them.

TABLE III.—*Machine Tools: United Kingdom Exports.*

Monthly Average.	Volume. Tons.	Index. (1913 = 100.)	Value per ton.	Index. (1913 = 100.)
1913	1,378	100	61·2	100
1931—				
1st Qr.	998	72	150·6	246
2nd ,, ...	982	71	146·7	239
3rd ,, ...	1,019	73	133·5	218
4th ,, ...	1,874	136	137·0	223
1932—				
1st Qr.	2,020	147	134·6	220
2nd ,, ...	2,048	149	147·9	242
3rd ,, ...	2,133	155	113·6	186
4th ,, ...	1,742	126	129·4	211
1933—				
1st Qr.	1,006	73	152·3	249
2nd ,, ...	803	58	145·0	237
3rd ,, ...	565	41	133·4	218
4th ,, ...	593	43	130·4	213
1934—				
1st Qr.	689	50	131·5	215
2nd ,, ...	1,150	84	123·3	201
3rd ,, ...	1,201	87	134·1	219
4th ,, ...	1,033	75	141·0	230
1935—				
1st Qr.	1,427	103	133·8	219
2nd ,, ...	1,413	102	128·6	210
3rd ,, ...	1,346	98	133·9	219
4th ,, ...	1,316	95	148·8	243
1936—				
1st Qr.	1,044	76	146·7	240
2nd ,, ...	1,326	96	140·6	230
3rd ,, ...	1,078	78	150·0	245
4th ,, ...	1,182	86	144·8	236
1937—				
1st Qr.	842	61	171·9	280
2nd ,, ...	886	64	182·4	298
3rd ,, ...	1,055	77	170·7	279
4th ,, ...	1,183	86	195·4	319
1938—				
1st Qr.	1,345	98	193·2	316
2nd ,, ...	1,891	137	176·6	288
3rd ,, ...	2,118	154	189·5	310
4th ,, ...	2,701	196	184·1	301
1939—				
1st Qr.	2,999	217	164·4	258
2nd ,, ...	2,532	184	180·2	299
3rd ,, ...	2,777	201	157·8	256

British exports of machine tools, in the first eight months of 1939, amounted to 22,148 tons, valued at 3,714,000*l.*, a very substantial advance over the figures of 13,560 tons and 2,549,000*l.* recorded for the corresponding period of the previous year. Exports by classes are shown in Table II, page 272, and it will be seen that there was an increase in every category. The largest increase was in the case of lathes, which were considerably the most important category in 1939 and accounted for just under 30 per cent. of the total exports. The second largest category was planing and shaping machines, and here again a substantial improvement took place compared with the previous year. Punching and shearing presses, milling machines and boring mills all showed considerable increases, but drilling and grinding machines showed only a slight advance. Exports are compared by volume in Table III.

Unfortunately for the future outlook for British exports, practically the whole of the increase in 1939 was due to increased exports to the U.S.S.R., which took 12,168 tons, valued at 1,740,000*l.*, or 55 per cent. of the total exports (by volume) in 1939, against only 4,609 tons valued at 792,121*l.* in the corresponding period of 1938, and 400 tons in 1937. The only other countries of any importance, exports to which increased in 1939, were Australia, which took 2,468 tons, compared with 1,390 tons; and France, which took 1,084 tons, against 502 tons. On the other hand, exports to India showed little change, while those to South Africa and Japan declined.

International exports of machine tools by volume and value are shown in Tables IV and V, below. In the period January to August, 1939, there was a further rise in the total volume of international trade, but exports from foreign countries did not increase to the same extent as British exports. As a result, the British share, by volume, of the total exports from the United Kingdom, France and Switzerland, rose from 20·5 per cent. in 1938 to 25·2 per cent. in the first eight months of 1939. Similarly, the British share by value of total exports from the above countries and the United States rose from 10·7 per cent. to 11·4 per cent. The increase was achieved mainly at the expense of Germany, whose share by volume fell from 66·4 per cent. to 62·4 per cent., and by value from 34·4 per cent. to 33·2 per cent. Exports from the United States, which are available by value only, were well maintained, and accounted for 47·8 per cent. in both years.

Although, as shown above, the improvement in the British position was due entirely to heavy deliveries to Russia, there would seem to have been some improvement in the competitive position of British manufacturers, since the average value per ton of British exports fell from 185*l.* in 1938 to 162*l.* in the first eight months of 1939, while German exports rose from 183*l.* to 196*l.* Arguments based on average value per ton, however, must be read with reserve, owing to the wide range of products covered by the term "machine tools." The spread in the average value per ton for various types of machine tools is shown in the accompanying Table VI.

TABLE VI.—*United Kingdom: Average Export Values of Machine tools.* (*£ per ton.*)

—	1937.	1938.	1939 (Jan.-Aug.).
Boring mills	123	140	133
Drilling	161	175	168
Grinding	212	262	248
Lathes	186	215	206
Milling	252	236	264
Planing and shaping ..	126	118	109
Presses, punching and shearing	97	97	81
Other sorts	220	173	137
Total	181	185	162

The figures show that the decline in average value was spread over all classes with the exception of milling machines and, while this may be due to the fact that the Russian purchases were confined to the cheaper types of machine tool, it is quite probable that the re-organisation of the British industry and the larger scale of production have resulted in a definite lowering of production costs.

The comparative failure of British manufacturers to expand exports to markets other than Russia has, undoubtedly, been a weakness in past years. Since 1931, the only years in which British exports have exceeded 17,000 tons were 1932, 1938 and 1939; and exports to Russia amounted to 19,234 tons in 1932, 10,109 tons in 1938, and 12,168 tons in the first eight months of 1939. In fact, the sharp fluctuations over the past decade in total British exports have been due mainly to the irregularity of Russian purchases. There is a strong case, therefore, not only for expanding the capacity of the industry to meet the greatly increased home demand, but also for intensive development of exports to countries other than Russia. In 1938, the principal markets for German exports were Japan (11,249 tons), Great Britain (8,985 tons), Italy (7,927 tons), Poland (5,348 tons), Rumania (4,092 tons), Holland (3,771 tons), Brazil (3,497 tons), France (3,380 tons), and Russia (3,154 tons). The quantities, in each case, are in metric tons. Germany has lost the British and French markets, but she is likely to be called upon to supply greatly-increased quantities to Russia. It may prove difficult to compete with Germany effectively in Italy, Rumania, Holland, and other important European markets (which include Sweden, Switzerland, Yugoslavia and Hungary), though the recent large British raw-material purchases in the Balkans may give assistance. In view of the difficulties of transport between Germany and Japan since the imposition of the Contraband Control, there would seem to be better prospects of an expansion of British exports in this direction. It is worth noting that total German exports to overseas countries amounted to 15,186 metric tons (excluding Japan), or rather more than the total British exports to Russia, which it is to be presumed will not

TABLE IV.—INTERNATIONAL EXPORTS OF MACHINE TOOLS (VOLUME).

	1933.		1934.		1935.		1936.		1937.		1938.		1939.*	
	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.
United Kingdom ..	8,900	9·8	12,218	15·4	16,446	24·7	13,886	14·7	11,897	9·2	24,167	20·5	22,148	25·2
Germany	76,159	83·5	60,639	76·7	42,877	64·2	72,063	76·1	100,746	78·1	78,359	66·4	54,980	62·4
France	4,453	4·9	4,255	5·4	4,890	7·3	5,440	5·7	11,647	9·1	10,357	8·8	6,761	7·7
Switzerland	1,641	1·8	1,994	2·5	2,556	3·8	3,296	3·5	4,603	3·6	5,001	4·3	4,189	4·7
Total	91,163	100·0	76,106	100·0	66,769	100·0	94,685	100·0	128,893	100·0	117,974	100·0	88,078	100·0

* January to August.

TABLE V.—INTERNATIONAL EXPORTS OF MACHINE TOOLS (VALUE £000's).

	1933.		1934.		1935.		1936.		1937.		1938.		1939.*	
		Per cent.		Per cent.		Per cent.		Per cent.		Per cent.		Per cent.		Per cent.
United Kingdom ..	1,267	9·3	1,610	11·8	2,243	14·2	2,014	8·6	2,152	6·6	4,476	10·7	3,715	11·4
Germany	8,903	65·7	6,350	46·4	5,775	36·5	10,276	43·7	14,825	45·7	14,247	34·4	10,780	33·2
United States	2,255	16·6	4,320	31·6	6,075	38·4	9,277	39·5	13,001	40·1	19,802	47·8	15,537	47·8
France	574	4·2	568	4·2	620	3·9	561	2·4	833	2·6	937	2·3	785	2·4
Switzerland	574	4·2	815	6·0	1,103	7·0	1,359	5·8	1,603	5·0	1,977	4·8	1,707	5·2
Total	13,573	100·0	13,663	100·0	15,816	100·0	23,487	100·0	32,414	100·0	41,529	100·0	32,524	100·0

continue. Some part of this total is accounted for by countries in South America, and undoubtedly strong competition will be experienced from United States manufacturers in these countries.

As regards Japan, mention was made in this series last year of measures put into force to expand production in that country. In pursuance of this policy, it was announced in September, 1939, that an important machine-tool manufacturing company was being formed in Manchukuo as a subsidiary of the Manchuria Arsenal Company. It was reported that the capacity of the new company would be yen 20 millions.

The price controversy between British manufacturers and the Government, which arose owing to the refusal of the former to allow Government inspection of their books, was settled in June, 1939, when an agreement was concluded between the manufacturers and the Ministry of Supply. Announcing the agreement in Parliament, Mr. W. S. Morrison said that the Machine Tool Trades Association had agreed that a discount of 5 per cent. should be given on all standard machine tools supplied for the purpose of the arms programme after December 5, 1938. In the case of non-standard machine tools, if the Government so desired, prices would be fixed after costs had been investigated by Government accountants. It was stated that the prices ruling on December 5, 1938, would hold good for one year and provision was made for revision where necessary owing to upward or downward movements in basic costs, such as the price of pig iron. It was also agreed that individual members of the Association should have the right to approach the Government with a view to modification of the agreement in cases where it was considered that hardship would result from its application.

Nevertheless, the machine-tool manufacturers did not escape further criticism in the Report of the Select Committee on Estimates, published at the end of July, 1939. This stated that, in the case of this industry, there appeared to be *prima facie* evidence that, to some extent, excessive profits were being made. The Committee, however, welcomed the agreement mentioned above. Since the setting up of the Ministry of Supply, of course, the Government have had the power, under the Ministry of Supply Act (1939) and Regulation 55 of the Defence Regulations, to compel the production of books. In addition, since the outbreak of war, the Control of Machine Tools (No. 1) Order, 1939, published on October 6, 1939, has conferred on the Government a very wide measure of control over the industry. The Order provides that every person engaged in the production, keeping, distribution, disposal, acquisition or use of machine tools in the United Kingdom shall comply with any directions or instructions issued by the Ministry of Supply. It is provided, also, that such books, accounts and records, as the Minister may require, shall be kept.

Full details of the negotiations between the Government and the Machine Tool Trades Association have not been published, but, assuming that ample facilities were available to the Government for checking prices before the agreement was reached, the terms would seem to confirm, to some extent, the claims of the manufacturers that their prices were reasonable, and were well below the corresponding prices of American or German machine tools before adding the 20 per cent. import duty. The importance of preventing excessive prices for machine tools will be generally admitted, but at the same time, the special position of manufacturers must be taken into account. Owing to the serious effect on machine-tool manufacturers of any recession in general industrial activity, the dividends of the majority of companies, when averaged over a number of years, have not been excessive, even though dividends in individual years have been high. Moreover, the sharp fluctuations in profits have made the industry particularly vulnerable to the Armaments Profits Duty.

Whatever the long term prospects for the industry—and, as pointed out above, these depend very largely on how far exports can be maintained—there can be no doubt that it will be very fully employed throughout the war. During 1939, practically all manufacturers announced extensions to plant and a definite shortage of skilled workers was felt, with the result that overtime working became general. No serious shortage of raw materials has yet been reported, although some manufacturers have complained of difficulty in obtaining adequate supplies of large castings.

EARLY ELECTRICAL PIONEERS.

By G. WINDRED.

THE object of this article is to give a short account of the work of two pioneers in the construction of electrical machines, namely, Sören Hjorth (1801-1870), of Denmark, and Ányos Jedlik (1800-1895), of Hungary. References to Hjorth in electrical literature are very rare, and the author knows of no published account of Jedlik's work in connection with electrical machines, except that to which reference is made in the present article. It appears that the labours of both men are of fundamental importance, and deserving of greater recognition than has been afforded to them hitherto. The life of Sören Hjorth has been told by Sigurd Smith in a little book* which was published in English and Danish at the expense of the Carlsberg Foundation and distributed among interested institutions throughout the world. The following information is based on this account.

Sören Hjorth was born on October 13, 1801, and spent his childhood at Vesterbygaard in Jordlöse Parish, north of Tissö. He passed an examination admitting him to the Bar, and later became steward of the Bonderup Estate, near Korsör, a seaport on the west coast of the Danish island of Zealand. In 1828 he entered the service of the State Treasury in Copenhagen, and in 1836 became Clerk to the Exchequer and Secretary. It is recorded that he made numerous more or less unsuccessful experiments with steam engines, commencing in 1832, so that this work must have been going on while he was in the service of the Treasury. In 1834, with the aid of the Rejersen Foundation and the Government, he visited England to acquaint himself with the use of steam cars on road and rail. During these years he attended lectures at the Polytechnic Institute, and was especially interested in Oersted's lectures on electricity and magnetism. After a visit to England, France and Belgium in 1839, he returned to Denmark and spent some years as manager of a piano factory. This occupation seems to contrast strangely with his obvious interests in other directions, but allowances must be made for the state of engineering development at the time.

In 1842, Hjorth prepared a design for an electromagnetic machine consisting of a stationary circle of magnets, the poles of which faced the poles of a movable circle of magnets. In 1843, this sketch was deposited with the Royal Scientific Society, but Sigurd Smith states that the sketch itself, as well as the explanation belonging to it, is very incomplete. Soon after his arrival in London in the summer of 1848, Hjorth became acquainted with a nephew of Joseph Bramah (1748-1814), of mechanical engineering fame. A partnership was formed, and two machines were made under Hjorth's instructions by Robinson and Sons, of Pimlico. Application for a patent was filed in London in October, 1848, and Patent No. 12295 (1848) was granted on April 26, 1849. Hjorth was invited to show the machine at the Royal Society, and at the Institution of Civil Engineers, of which he was an associate member. It was exhibited at the Great Exhibition in London, in 1851, and received the only prize medal awarded to electromotive power.

On May 1, 1851, Hjorth wrote in his sketch-book the following important note, beside a sketch of a machine having copper discs for armature conductors and cast-iron electromagnets:—"By passing the current in the said way round the electromagnets, these will, of course, be excited in proportion to the strength of the same, and the more they are excited, the more will the discs be influenced by the magnets, a mutual action thus taking place." From this statement, it certainly appears that, at this early date, Hjorth had clearly described the principle of self-excitation. On October 14, 1854, he patented another machine employing the same principle (Patent No. 2198, 1854). Sigurd Smith states that a machine patented in 1855 (Patent No. 806, 1855) was built by Messrs. Malcolm and Campbell, 7, India-buildings, Liverpool. It would be interesting to discover whether anything is now known of this machine.*

It remains only to record of Hjorth, as of so many other pioneers in scientific progress, that, failing to obtain adequate recognition of his work, he died in reduced circumstances, on August 28, 1870. Thus terminated a life of varied and earnest endeavour, which resulted in a valuable but neglected contribution to electrical engineering development, deserving to rank with the foremost discoveries of the period.

Such references to Hjorth as are to be found in electrical literature are scant. In an article by Dr. Rudolf Richter on the study of the history of electrical machines in the college at Karlsruhe, there is an interesting table of historical information with photographs showing the history of direct-current machines. This begins with Faraday's electromagnetic rotations of 1821, and traces the development pictorially through the fruitful years up to the end of the Nineteenth Century. Werner von Siemens is named as the discoverer of the dynamo-electric principle of self-excitation in 1867, and beneath his photograph it is mentioned that Hjorth also made the discovery ten years earlier, without developing it. In an historical treatise† on the dynamo-electric machine, published in Russia a few years ago, Hjorth is again named as the first to use the self-excitation principle.

An excellent account of the life and work of Ányos Jedlik is given in a paper‡ by Professor L. de Verebélÿ, presented at the Jedlik Centenary of the Hungarian Electrotechnical Society, on May 3, 1928. From this it appears that Jedlik was born on January 11, 1800, at Szémö, in the county of Komarom in Hungary, where his people were "simple and poor farmers." In his seventeenth year, after schooling at Nagyszombat and Pozsony, he entered the St. Benedictine order. This step is described as being at his parents' desire, and following his own inclination. It was in Pannonhalma Abbey that he received his monastic training and higher scientific education, leading to his receipt of the doctorate of philosophy in 1822. He was ordained priest in 1825.

Jedlik then commenced his long career as a teacher of physics, firstly at Pannonhalma and afterwards at Györ. In 1830 he went to the Academy of Pozsony, and in 1840 was appointed a professor of physics in the University of Pest, where he remained for 38 years. Jedlik's own work in physics was of a practical rather than a theoretical kind, as he was not trained in higher mathematics. This may be regarded as a contemporary tendency, and for the problems of his day mathematics was not the indispensable tool that it is now. His writings cover a wide range of subjects, including optics and various branches of electrical physics.

The work with which this article is concerned was recorded by Jedlik in an "Inventarium," dated 1859, in the possession of the Physical Institute of the University of Sciences in Budapest. Part of this record deals with his "unipolar inductor, invented by Ányos Jedlik, made in Nuss' mechanist's shop in Pesth." This was "procured in 1861, Price 114 Fl. 94 kr." The machine itself, fortunately,

* *Sören Hjorth, Inventor of the Dynamo-Electric Principle.* By Sigurd Smith. *Elektroteknisk Forening*, Copenhagen, 1912. See ENGINEERING, vol. 93, page 715 (1912).

* In ENGINEERING of November 5, 1912, we printed a letter inquiring for information as to the whereabouts of this machine. Our correspondent stated that "it was presented to the Polytechnic, Regent-street, in May, 1857. The machine is reported to have been seen in one of the London museums as late as 1895." An illustration of the machine accompanied the letter. Unfortunately, the inquiry elicited no response.—ED., E.

† *The Dynamo-Electric Machine in its Historical Development.* By D. V. Efremov and M. I. Radovskij. Leningrad: Academy of Sciences Press, 1934.

‡ *Anyos Jedlik, A Hungarian Pioneer of Electricity*, By L. de Verebély. Budapest: *Elektroteknika*, November 15, 1931.

IGNITRON CONTACTOR FOR SPOT WELDERS.

MESSRS. BRITISH THOMSON-HOUSTON COMPANY, LIMITED, RUGBY.

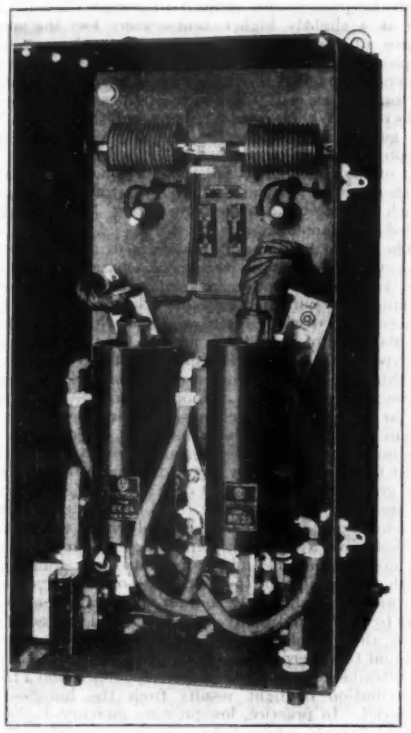
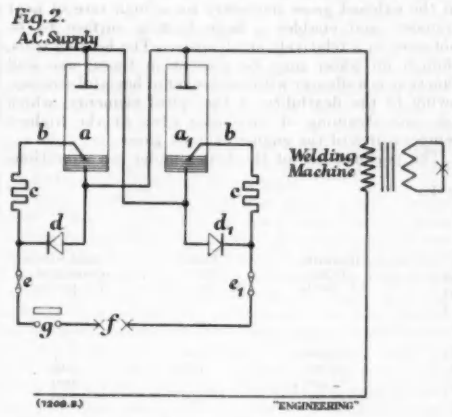
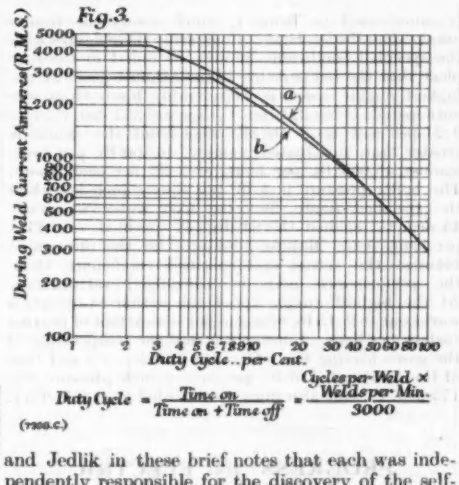


FIG. 1.





is still extant, and is accompanied by a description, in Jedlik's manuscript, which includes a diagram of connections. The arrangement of the whole machine shows a high degree of ingenuity and a full appreciation of the laws of electromagnetic induction. It is a somewhat complicated device, having two distinct sets of windings, corresponding, respectively, to the "magnet" and the "multiplier." By suitably interconnecting the terminals and inserting a battery, the current is caused to flow through both windings, causing the magnet to rotate rapidly around its axis.

The important part of the description, from the present viewpoint, is contained in clause 4, which states that if the terminals are connected as before, but with a galvanometer in place of the battery, "an electric current is induced in the multiplier's windings in consequence of the rotation of the magnet, which current passing through the winding of the rotated magnet, makes the magnet stronger, this latter inducing again a still stronger current, and so on." Here is a clear enunciation of the principle of self-excitation, incorporated in a machine made some time before 1861, or at least six years before the almost simultaneous announcement of the same principle by Werner von Siemens and Sir Charles Wheatstone.

There seems to be no reasonable doubt that Jedlik was unaware of the practical implications of his discovery. Perhaps this is best explained as in Professor Verebélÿ's article: "In the sublime domain of his science Jedlik was, however, a fervently researching scientist and not an artisan nor an industrialist looking for the ways of practical application. He possessed the divine spark of a genius, which flashed up more than once within the quiet walls of his laboratory, but it did not kindle a torch to light up the way of mankind's progress. The credit for this is due to Pacinotti, to Gramme and especially to Siemens and Wheatstone who were, it is true, not so far removed from real life, and who were also not confined to work at the University of an oppressed poor country, as Jedlik was in Hungary."

It appears from what has been stated of Hjorth and Jedlik in these brief notes that each was independently responsible for the discovery of the self-excitation principle, upon which the development of the dynamo has been so largely dependent. In neither case, apparently, was any attempt made to extend the discovery in a practical way, as was done by Siemens and Wheatstone, to whom the commercial form of the development must still be credited.

IGNITRON CONTACTOR FOR THE CONTROL OF SPOT WELDERS.

ELECTRIC spot welders are now constructed with loadings up to as much as 1,000 kVA, and a maximum speed as high as 200 operations per minute. This means that currents of 1,000 amperes or more have to be interrupted, a duty which naturally causes a severe strain on the ordinary magnetic contactor used for switching purposes. The employment of such contactors limits the number of operations to about 100 per minute, and, when they are used, variations in the duration of the welding period will occur at high speeds and correspondingly short welding times, owing to the tips of the contactor opening and closing at different points on the voltage wave. Serious transient currents can also be caused by the contactor tips closing too near the zero-voltage point and thus adversely affecting the weld. Other points are that a contactor for such duty has to be large if tips are not to "freeze" and cause damage to the work. It is also rather objectionably noisy in operation, and its cost is high.

The British Thomson-Houston Company, Limited, Rugby, have attempted to overcome these difficulties by designing the Ignitron contactor, an illustration of which appears in Fig. 1, above. This consists of two steel Ignitrons, connected reversely in parallel, together with their igniter control circuits. Each Ignitron consists of a permanently-sealed evacuated steel cylinder, at the bottom of which is the cathode lug. This lug is integral with the cylinder end. The anode is carried on an insulating glass seal at the top of the tube and the igniter is supported from an insert of the same material in the bottom of the tube, which also contains the necessary amount of mercury. Ignition is effected by passing a momentary current through the igniter element, the conical tip of which is permanently immersed in the mercury pool. Arrangements are made so that, when the igniter circuit is passing this momentary current, the anode is positive with respect to the cathode pool. The anode is therefore allowed to pass current when ionisation takes place at the igniter. The Ignitron is provided with a water jacket, which is proportioned to provide effective cooling, thus allowing the mean current rating to be increased above what would be permissible with air cooling. A water-flow switch prevents the operation of the equipment should the cooling-water flow fall below the minimum of 1½ gallons per minute.

The Ignitron contactor is connected in circuit between one of the alternating-current supply lines and the primary of the welding transformer in the same way as a single-pole magnetic contactor, as shown in Fig. 2, while the control circuits are brought out to two control terminals. When a circuit is made across these terminals the Ignitrons will pass current until the circuit is opened. Referring to the diagram in more detail, it will be seen that the two Ignitrons, a and a_1, are connected reversely in parallel and their igniter circuits b are virtually connected in parallel. It will be noted that each igniter and its protective resistance c is substantially shunted by metal rectifiers, d and d_1. This is done to limit the reverse current carried by each igniter. For instance, assuming that the anode of Ignitron a is positive with respect to its cathode and it is, therefore, desired to ignite it, when the circuit is closed between the control terminals, current will flow from the anode of Ignitron a through the direct connection to the cathode of Ignitron a_1. Here the current path divides, the greater portion flowing through the rectifier d_1, while the remainder will flow through the igniter of Ignitron a_1 as reverse current. The circuit will be continued through fuse e_1 to the timing device f, the water-flow switch g and the fuse e, when it will again divide. The rectifier d will pass a small reverse current, but the greater portion will flow through the igniter b of Ignitron a to the pool cathode and thence through the load back to the mains. It will be seen that the igniter b of Ignitron a thus receives a heavy current impulse and, therefore, Ignitron a will fire. When the load current ceases to flow through Ignitron a, it will be extinguished, and at this instant an appreciable positive voltage will be present on the anode of Ignitron a_1, due to the inductive load. Ignition of this tube will then follow in a similar manner. Conduction of the two Ignitron tubes alternately will continue until the control circuit is broken. Since a voltage must exist across the igniter circuit in order to cause the current flow which brings about ignition, it follows that this cannot take place near the zero-voltage point at which current transients in the power circuit will be most damaging. This, it is claimed, explains why the Ignitron contactor will give more uniform welds than the magnetic contactor, which can close the power circuit near the zero-voltage point on the first half cycle of any weld.

While the Ignitron contactor is intended primarily for the control of spot-welding machines, it can also be used on projection welders. It is not, however, suitable for seam welders, for which full electronic synchronous control is necessary. It should also be noted that the Ignitron contactor is not provided with any weld-timing device. Any suitable form of timer can be used, though one of the electronic pattern will give the most consistent results, especially with short welding times. The Ignitron contactor will operate over a range of single-phase voltages from 200 to 550 without any alteration or adjustment and its rating at these two pressures is shown in curves a and b, respectively, in Fig. 3.

LA MONT WASTE-HEAT BOILER IN M.S. "HAV."

ALTHOUGH the La Mont forced-circulation boiler has already been described in these columns, the installations dealt with have been directly fired, in both land and marine instances. The present account, illustrated by Figs. 1 to 5, on page 282, relates to a La Mont boiler arranged for utilising the waste heat of the exhaust gases from a marine internal-combustion engine. The boiler has proved to be very effective in this capacity since the first of its type was installed in the motorship Toulouse in 1933, and a considerable number have been fitted. The installation now dealt with is one of the latest, the acceptance trials having taken place at the end of August, 1939, and presents a number of interesting features. It is fitted in the motorship Hav, a vessel built by Messrs. Swan, Hunter and Wigham Richardson, Limited, Wallsend-on-Tyne, and engined by them with a Doxford engine developing 3,000 to 3,200 brake horse-power. The

waste-heat boiler, constructed under licence by Messrs. Ivor Power Specialty Company, Limited, King's Langley, Hertfordshire, is situated in the exhaust-pipe line above the shelter deck, as shown in the lay-out, Fig. 1. The course of the gases is straight through the boiler, and presents no bends. Steam is required for operating auxiliaries, cabin heating, etc., and for harbour work, when the engine is not running, is supplied by two oil-fired cylindrical boilers situated in the wings of the engine room.

The oil-fired boilers are coupled in parallel with the waste-heat boiler, as shown. There are two circulating pumps, drawing from the lower part of the oil-fired boilers and delivering to the coils of the waste-heat boiler, the steam and excess water from this boiler being delivered to the steam space of the oil-fired boilers. Examination of the lay-out will show that either circulating pump can draw from either boiler, that both the oil-fired boilers can be steamed simultaneously, or one can be isolated, either pump also being capable of being cut out of the circuit. The arrangement is thus a very flexible one. The waste-heat boiler is shown in detail in Figs. 2 to 5. It has a total heating surface of 840 sq. ft., and was designed to deal with exhaust gases to the amount of 4,500 lb. per hour, the specified temperature of the gases on entering the boiler being 357 deg. C. and on leaving it, 232 deg. C. The specified steam output was 2,400 lb. per hour at 120 lb. per square inch, from feed water at a temperature of 94 deg. C. The boiler, as regards its general design, is of the type previously described, but the heating surface, instead of being arranged in a more or less box-like form to enclose a combustion chamber, consists of a number of spiral coils arranged transversely to the gas flow and staggered in alternate layers so that the flow is virtually in contact with the whole surface. The coils are made from cold-drawn mild-steel tube, 1¼ in. in external diameter, and their ends terminate in two headers serving as the distributor and collector, respectively.

The coils were referred to above as being of spiral form, but this description is somewhat incomplete. Each is a double spiral, being formed in two layers; the tube is reflexed on itself at the centre, as shown in Fig. 5, so that one coil of each layer lies below the other. As will be seen in Fig. 3, there are 23 double coils, *i.e.*, 46 layers in all. The header seen in this illustration is the distributor, from which header the coils receive the feed water delivered under pressure from the circulating pumps. At the bottom of the boiler, which is the area subjected to the hottest gases, there are ten double-spiral coils, each of which derives its supply from the header, and from each the steam and excess water is delivered to the collector header, seen to the left in Fig. 2, and further identified by the safety valve on top of it. Each of these coils is, therefore, a separate water passage. Higher up there are ten more double-spiral coils, but in these each double-spiral is connected to one adjacent to it in series, so that the water passage is through only five elements and there are only five connections at both the distributor and collector headers. At the top of the boiler are three double-spiral coils, also coupled in series, and with only one connection to each header. This arrangement can be made out, in Fig. 3, from the extensions of the coils to the right, these extensions representing the loops between those double-coils which are connected up in series.

There are thus 16 connections on the distributor header, but they do not serve identical lengths of tube in each case. Thus, the tubes in the top unit are three times as long as those in each of the ten bottom units, and those in each of the five middle units are twice as long. In consequence, the resistance of the steam-water mixture passing through the tubes will vary and so each connection on the distributor header is fitted with a nozzle calibrated to regulate the supply of water in definite proportions relatively to this resistance and to the evaporative capacity. A detailed illustration of this nozzle will be found in ENGINEERING, vol. 142, page 412 (1936). Similarly, there are 16 connections to the collector header. The connections on each header, however, are differently spaced, as will be evident from Fig. 2. This view shows the removable flat cover over the headers for access to the plugs situated opposite to the connections, the connections being expanded into the headers. The headers lie in a recess built out from the boiler casing, as shown in Fig. 4. The casing is split vertically down the centre so that one half can be removed to expose the coils for purposes of inspection. It will be appreciated that the staggering of the coils creates that degree of turbulence in the exhaust gases necessary for a high rate of heat transfer, and enables a large heating surface to be obtained in a relatively small space. The heating coils, though no water may be present in them, can still function as a silencer without danger of harmful stresses, owing to the flexibility of the spiral elements, which prevents straining of the joints even at the highest temperatures of the engine exhaust gases.

The performance of the boiler under sea conditions is summarised in Table I, which shows the results obtained on the sea trials. Comparing these figures with the specified conditions, it may be noted in the first place that the temperature of the exhaust gases at the highest engine speed is considerably lower than was anticipated, being 324 deg. C., against 357 deg. C., *i.e.*, 9·24 per cent. less. On the other hand, the volume is greater than anticipated, namely, 46,500 lb. per hour, against 45,000 lb. per hour, or 3·33 per cent. more. The boiler pressure is 4 lb. per square inch less than the specified figure, but the feed water was only 45 deg. C., against the 94 deg. C. specified, *i.e.*, 43·8 per cent. less. Making allowance for the differences between the actual and specified conditions, then, the performance may be considered satisfactory. At the highest engine speed the actual evaporation works out to 2·15 lb. of steam per square foot of heating surface per hour. Considering that the temperature of the gases leaving the boiler was 224 deg. C., and that of the steam at 116 lb. per square inch pressure was 175 deg. C., this also must be regarded as satisfactory.

TABLE I.

Engine r.p.m.	Temperatures. Exhaust Gas to Boiler. Deg. C.	Temperatures. Gas Leaving Boiler. Deg. C.	Temperatures. Feed Water. Deg. F.	Quantity of Gas. Lb. per hr.	Boiler Press. Lb. per sq. in.	Actual Steam Generated. Lb. per hr.
70·8	195	185	199	33,500	116	141
82·9	245	200	199	39,200	115	745
89·9	275	210	119	42,500	113	1,080
98·4	324	224	113	46,500	116	1,810

PROGRESS IN ELECTRIC ILLUMINATION.

THE current issue of the *Journal* of the Institution of Electrical Engineers contains a review of the progress that has been made in electric illumination during the past three years. This review has been written by Dr. C. C. Paterson, who points out that the period has seen the increasing influence of the electric-discharge lamp on lighting technique. The "breakaway" from filament-lamp lighting, mentioned in the last review,* has by no means constituted a landslide. Having regard to the proportion of filament to discharge lamps sold, the use of the latter is as yet on a very limited scale indeed. Nevertheless, the technical achievements over this period have been noteworthy, and the relatively high cost of electric-discharge lamps must probably be regarded as the chief factor in hindering their more extensive use. Every lamp still requires its own series choke-coil (or the equivalent), and the lamps themselves, although having longer lives than filament sources, cost several times more. They are, however, about three times more efficient, and the economic balance sheet per 1,000 hours' running is usually in favour of the discharge lamp. Experience indicates, however, that the purchaser gives more heed to first cost of a lamp than to overall running expense, and the utility company does not always find that devices which effect economies in electricity consumption are to its economic advantage. There are, of course, other factors, such as colour, form or novelty, which have weighed some on one side and some on the other, and the upshot has been a steady, though not rapid, increase in the adoption of electric-discharge lamps for those services for which they have special attraction. The developments to be recorded emanate mainly from Europe, but the United States have just shown a remarkable step forward in the large-scale production and marketing of 15-watt to 40-watt low-voltage luminescent discharge tubes, in spite of those adverse considerations just mentioned, which have so far prevented a similar popularity in England or on the Continent.

Filament lamps have shown but little change since 1935. It appears as though the coiled-coil filament marks the last major advance which is to occur in efficiency. It is true that the use of krypton in place of argon has been found capable of enhancing efficiency to some extent, because krypton, in a greater measure than the present argon, reduces the loss of energy from the filament resulting from conduction, so that a higher proportion of the total energy supplied to the filament is available for producing light. Owing to its heavier atom, krypton is also claimed to permit filaments to run at a slightly higher temperature for the same degree of tungsten volatilisation, *i.e.*, filament life. Improvements have been made by this means in small miners'-lamp bulbs, the light of which has been increased by some 20 per cent. without too serious an increase in bulb cost. Where, however, lamp bulbs are larger, as for general lighting-service lamps, the cost of the krypton appears to necessitate a serious increase in cost of the lamp. This has to be weighed against the further gain of efficiency (of the order of 10 per cent.) which might be achieved by using krypton with coiled-coil filaments.

The use of luminescent materials to add light and improve the colour of mercury discharge lamps bids fair to prove a major development. The powder technique is not so favourable when used with hot concentrated discharge sources as it is with the "cold" tubular type of lamps. At present the powders suffer if exposed to the temperatures which prevail in the neighbourhood of the inner component of the high-pressure mercury lamps. In order, therefore, to secure as far as possible the colour-improving properties of luminescent powders, the latter must be coated on to the inner surface of the outer glass envelope, and this must then be sufficiently large to ensure a temperature not greater than about 150 deg. C. By these means, as well as by changes in the inners, high-pressure mercury lamps have been marketed which, though not perfect, give a sufficiently improved colour rendering for advantageous use in industrial and open-air lighting. With the tubular low-pressure type of discharge lamp the walls are sufficiently cool for the luminescent powders to be coated directly on to them, and the radiation from the discharge then impinges on the powder without the interposition of any glass. The stimulation by ultra-violet rays is thus relatively intense and a large contribution of light results from the luminescent material. In practice, low-pressure mercury-discharge tubing, giving white light, the luminescent powder increases the light (and therefore the efficiency) some seven times. The luminescent material effectually corrects the colour of the light, which can apparently be modulated as desired. The first tubular sources to use luminescent powders were of the long high-voltage types. They were introduced in 1934, but in 1938 have appeared short mains-voltage luminescent lamps consuming from 10 watts to 40 watts. These lamps do not at present compete in any outstanding way with tungsten lighting on the ground of economy, for the cost of the lamps and of their auxiliary gear counterbalances the greater light efficiency. Their popularity arises from the same reasons which made the high-voltage tubular lamp attractive, *i.e.*, low brilliancy, well-chosen hue of light, tubular form, and low heat. With these lamps, for the first time, almost any colour or any shade of daylight can be obtained, from sunlight to cold north skylight, at good efficiencies.

Sodium lamps have held their own, in popularity, with mercury lamps, and their running efficiency has been increased by about 15 per cent. The rivalry between mercury and sodium in general effectiveness continues acute and is usually decided in each instance in accordance with the preference of the purchaser for one colour or the other. The use of quartz as a material for the envelopes of lamps, common practice for many years for ultra-violet lamps, has now been introduced for normal lighting lamps with interesting effects. A capillary discharge in a quartz tube only 4 mm. diameter and 10 mm. long can dissipate 40 watts in air, but if the tube is cooled by water this dissipation can be raised ten times with an increase of brilliancy—though not of efficiency. The quartz air-cooled capillary lamp ensures about the same efficiency (about 40 lumens per watt) for low wattages as is given by 250-watt and 400-watt high-pressure mercury lamps in glass envelopes. Lamps of this type, of 125 watts and 80 watts, have consequently been introduced into the general lighting service group of lamps. Apart from the use of quartz in lamps for general lighting, this material constitutes the key to really high intrinsic-brilliancy lamps for projection purposes. Such lamps, using mercury vapour at from 15 atmospheres to 150 atmospheres pressure, yield brilliancies (in candles per square millimetre) from 10 times to 50 times that of the ordinary tungsten filament—brilliancies which approach, but do not quite attain, that of the high current-density arc. Such quartz projection lamps are either water- or air-cooled. The 500-watt size of the former has a small column about 12 mm. long and 1 mm. diameter—while the 500-watt air-cooled type approximates more closely to a point—and consists of an arc about 5 mm. long and 2·5 mm. wide between electrodes, at the centre of a small quartz bulb approximately 4 cm. diameter. Such a

* *Journal I.E.E.*, vol. 78, page 171 (1936).

source is so concentrated that optical-projection apparatus which is not optically worked, is often not perfect enough to take advantage of the small dimensions. It would appear that a step forward is now due in the perfection of mirrors and the like used for projection with such sources.

No new lamp has yet arrived on the market which, for domestic lighting, will compete in overall cost with the low-wattage filament lamp, but where cost is not the main consideration the advantage of tubular forms of light is now recognised. The popularity of these has increased, as also has the provision in living rooms of entirely decorative devices which depend for their effectiveness on the strong and æsthetic illumination of some object of intrinsic charm or dignity. The tubular type of lighting is also appearing in factories for places where its distributed character is of special advantage to the process concerned. For utility factory lighting, however, the chief change lies in the adoption of either high-pressure mercury or sodium lighting in points placed well up. By this means high illumination levels are attainable at relatively low running cost. Particularly has this been the case in the high factory buildings put up for munitions production.

The lighting of shops, shop windows and offices, has been helped in efficiency and in effect by lucidaries using combined tungsten and mercury lamps in such a manner that the light from them is mixed before it reaches the objects to be lighted. The general level of illumination provided tends still to rise—that is to say, more establishments employ the higher levels above 20 foot-candles which had already been shown for many industrial processes to be economically sound.

The creation of optimum conditions for seeing with a minimum of light has been forced on illuminating engineers by war time "blackout" conditions. Looked at technically, this is not a retrograde condition, for so long as plenty of light is available the incentive to study the science and art of good seeing in its absence does not operate. It is realised that under these conditions the fundamental desideratum is to aid seeing when the human eye is adapted for virtual darkness. The tendency in street lighting has been to bring up the levels of light to such a point that the eye is operating in a condition well removed from dark adaptation. When, however, as in the blackout, the eye finds itself dark-adapted, many aids to vision are possible which would otherwise and in most situations be unwanted. Such aids to vision are (*a*) the complete elimination of light sources which can be seen near the line of vision, and in any case the reduction of the intensity of any light to a level which is no more than a glimmer; (*b*) the enhancement of normal contrasts by the use of large surfaces of low brightness, which may, of course, consist of whitewashed areas; and (*c*) the employment of safe automobile or hand-torch beams for back reflection from light surfaces or from reflectors fixed to surfaces. The improvement of appropriate highway markings to assist seeing in the virtual absence of artificial light has shown marked progress and will probably remain of value even when normal lighting on highways is restored.

The interim report of the Departmental Committee on street lighting was mentioned in the last progress review. This committee brought out its final report in August, 1937. The recommendations do not deviate from those of the interim report, but amplify and add to them. They confirm, for instance, the 25-ft. height and 150-ft. maximum spacing, and add valuable provisions for the correct location of lighting standards. This report holds the field as the main authoritative guidance for lighting authorities throughout the country. Most new installations conform with it so far as concerns height and spacing of sources and quantity of light, particularly in the case of trunk roads taken over by the Ministry of Transport, for the lighting of which the Government contribute a grant. The value of the provisions of the report are being realised for the placing of light in the most advantageous position for ensuring adequate brightness of the carriageway and of other backgrounds at the critical points on highways. Many modern installations now exist where the ideal of uniform and symmetrical placing of lights has been discarded in favour of the ideal of placing lights solely for the purpose of good seeing from the driver's viewpoint. It is being realised that each lamp in an installation makes its individual and unique contribution to the bright background of the highway and its surroundings against which objects are silhouetted. If a lamp is put out, a dark patch is thereby substituted for a bright one, and objects in this locality tend not to be seen. Most new trunk roads are of the dual carriageway type, and much investigatory work has been directed to their effective lighting, and particularly to their junctions and roundabouts. An interesting and promising trial has been made of lighting lengths of dual carriageway by "one way" lanterns throwing light only towards oncoming traffic. By this means the contrast of objects is enhanced so that they appear always as dark silhouettes and the driver sees only the lamps belonging to his own carriageway.

On the theoretical side, there has been active experimental study of "revealing power" under street lighting conditions. This is probably one of the most important contributions which has been made towards the determination of visibility in an artificially lighted road. By an analysis of the extent to which an installation will reveal objects present in it the effectiveness of the lighting may be gauged, and the calculations can be applied to any new system which may be devised. Study has continued of the extent to which the glare from street lamps, under different conditions, can affect good seeing—and the result shows itself in what is termed the control of cut-off, *i.e.*, the rate at which light intensity falls off over the small critical angle within which light is sent to distances beyond about 150 ft. from the lucidiary in question.

Civilian night-flying calls for lighting of various kinds in which uniformity of practice is desirable both nationally and internationally. Largely through the efforts of the International Commission on Illumination, it has been possible to obtain international agreement on the colour and arrangement of the lights used for marking boundaries, obstructions and the like, before independent techniques had been firmly established. At the Tenth Session of the Commission, held in Holland, in June, 1939, aviation lighting was again one of the subjects studied. Probably the most important new item on which agreement is desired is the arrangement and colour of lights used on and near the aerodrome for the facilitation of landings in fog. Agreement has been reached on the result desired, and the lines of further experiments have been laid down. The most notable technical progress in this field has been in the application of line-source high-pressure mercury-vapour lamps to aerodrome floodlighting. Air-cooled and water-cooled lamps have been used in the trough reflectors previously employed with linear tungsten-filament lamps, with considerable gains in beam candle-power.

The problems of photometry have been mainly two. The first is to apply the photocell to portable photometers. It cannot be said that this has increased the accuracy of portable photometers, but it has added greatly to their convenience and robustness. This is due to the use of the selenium rectifier cell, the ability of which to supply sufficient current at low voltage to deflect a sensitive ammeter made it peculiarly suitable for the purpose. Unfortunately, the ease and reliability with which it appears to work frequently deceive the uncritical user regarding the errors of its indications, which may arise from any one or a combination of the following causes: Differences between the spectral sensitivity of the photocell from that of the "average eye" may introduce errors of appreciable magnitude when comparing light from tungsten-filament lamps, with which the photo-electric photometer has probably been calibrated, with that from lighting installations employing light sources of different spectral energy distributions, *e.g.*, in some electric discharge-lamp installations. Other causes of errors may be: (*a*) departure from true cosine response; (*b*) non-linearity between the incident light and the photo-electric current, possibly not entirely corrected for in the scaling of the indicating microammeter; (*c*) fatigue effects giving rise to temporary reduction in sensitivity of the photocell after extended exposure to light; and (*d*) differences in the indications due to the temperature coefficient of the photocell.

The second and greater problem has been the correct measurement or appraisement of the light from discharge lamps. It is now appreciated that two lamps the light of which shows virtual colour identity may behave very differently in their revealing power when illuminating coloured objects. The extent of the difference depends upon the spectral distribution of light from the sources, because two lamps having from appearance the same hue may have very different spectral distributions. To help this problem, the lamp manufacturers have defined eight spectral bands, and the relative luminous intensity in each band of the light under examination is stated. For discharge lamps using luminescent powders an effort is to be made to define "colour," expressing it in terms of plus and minus limits of luminous intensity in each of these spectral bands. For expressing the apparent colour of the light, the trichromatic system is employed, but the user will not be troubled by these technical points and practical lamps will be known by their colour, expressed in everyday terms.

Measurement of the very low brightnesses associated with "blackout" conditions of vision is reviving the problem of visual photometry in a particularly exacting form. Nevertheless, it is important to establish a technique of measurement for such conditions. Before the war came, the world was at last promised (for January, 1940) a liquidation of some of the international candle-power differences which have occasioned trouble for the past 30 years. A "New Candle" was to be accepted by the National Laboratories of Great Britain, America, France and Germany, based on the light from a square centimetre of platinum at its freezing point and determined in a carefully defined manner with accurately specified apparatus. The unit of candle-power given by this was found to be very closely the same as that hitherto accepted in the first three of these countries. All nations supporting the Comité International des Poids et Mésures agreed to accept this standard with its resulting unit. It remains to be seen now whether this will in fact happen. If it does, the arrangement should also define the method to be used for stepping up in colour.

In the past, because of the difference in the colour of the light from the carbon standard lamps in which the old unit was maintained, and that from practical everyday illuminants, discrepancies tended to arise in the values assigned to these latter sources of light because the method of making the photometric comparison, or colour step, was not sufficiently accurately defined. For example, when calibrating tungsten-filament electric lamps of the gas-filled type, operating at colour temperatures some 1,000 deg. higher than those of the carbon standard lamps against which they must be calibrated, either directly or indirectly, differences of several per cent. can arise in the result obtained, depending on the details of the method and apparatus used, although all would be considered good photometric practice. The magnitude of such discrepancies increases with the difference in colour and spectral energy distribution between the light sources being compared. As the colour temperature of the light from the "New Candle" is not very different from that of the carbon standard lamps, similar difficulties would arise, but this situation will be avoided by defining the method to be used for "stepping up" in colour. The methods defined should be those which yield results in accordance with those of a hypothetical observer defined by the C.I.E. luminosity curve for the "average eye."

TWO-STAGE HORIZONTAL COMPRESSOR SETS.

THE water-cooled two-stage horizontal compressor sets shown in Figs. 1 to 8, pages 278 and 279, has recently been introduced by Messrs. The National Gas and Oil Engine Company, Limited, of Ashton-under-Lyne. Fig. 1 illustrates the compressor coupled up to a standard type "4 D" National four-cylinder Diesel engine and mounted on a cast-iron baseplate to form a stationary set, while Fig. 2 shows the same two units mounted on a carriage with radiator and storage tanks to form a portable set.

The compressor, illustrated in Figs. 3 to 6, is a three-cylinder unit, the two low-pressure cylinders being arranged vis-a-vis the high-pressure cylinder, as shown in the figures. This arrangement not only ensures excellent balance, but eliminates rocking couples which are present in some designs of compressor of the horizontally-opposed type. Apart from the symmetrical arrangement, good balance is further ensured by using light-alloy pistons for the low-pressure side, and a cast-iron piston for the high-pressure side, the weight of the cast-iron piston being equal to that of the two alloy pistons. The rotating mass of the extra crankpin on the low-pressure side is compensated by means of balance weights, shown in Figs. 3 and 5. The intercooler between the first and second stages is arranged in the water space underneath the sump, as shown in Figs. 3 and 6, the tubes running from one end of the crankcase to the other. A door underneath the compressor, shown in Figs. 3, 4 and 5, exposes the whole of the intercooler tubes for cleaning, while the bearings are readily accessible through a door over the crankcase, embodying the air cleaner. The latter is of the Vokes Protectometer type. The compressor valves, which, as shown in Fig. 3, are arranged in the cylinder heads, are of the low-lift type. They can be removed without disturbing the heads or breaking any pipe joints, each valve having its own separate cover. All the valve plates are interchangeable, thus reducing the number of spares required. By water cooling all parts of the compressor, a considerable reduction of air temperature, with a corresponding increase in efficiency, is obtained. The water enters the bottom of the intercooler, and passes upwards round the cylinders and through the cylinder covers, leaving at the top through the two pipes shown in Fig. 3. A certain amount of after-cooling is obtained by causing the air leaving the high-pressure cylinder to flow through a water-cooled passage and manifold before reaching the receiver. As regards the mechanical details of the compressor, the crankshaft is carried on two roller bearings, with a ball thrust bearing at the driving end, as shown in Fig. 5. It is of large diameter, and is forged in one piece from Siemen's acid mild steel. The shaft is subjected to the same tests and inspection as those employed for the crankshafts of the firm's large heavy-oil and gas engines. The crankcase is of very stiff box-girder design, and is of high-grade iron, with a large sump and ample water passages round the cylinders. The connecting rods are of H-section high-

TWO-STAGE HORIZONTAL COMPRESSOR SETS

CONSTRUCTED BY MESSRS. THE NATIONAL GAS AND OIL ENGINE COMPANY, LIMITED, ASHTON-UNDER-LYNE.

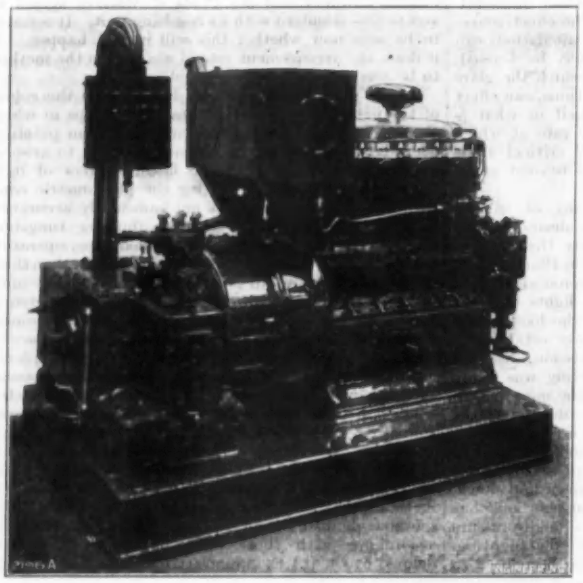


Fig. 1. Stationary Set.

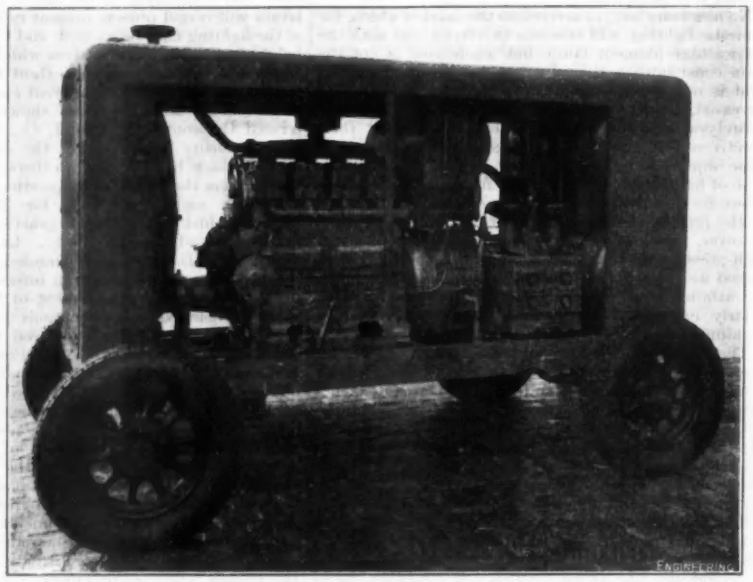


Fig. 2. Portable Set.

Fig. 3. SECTION AA

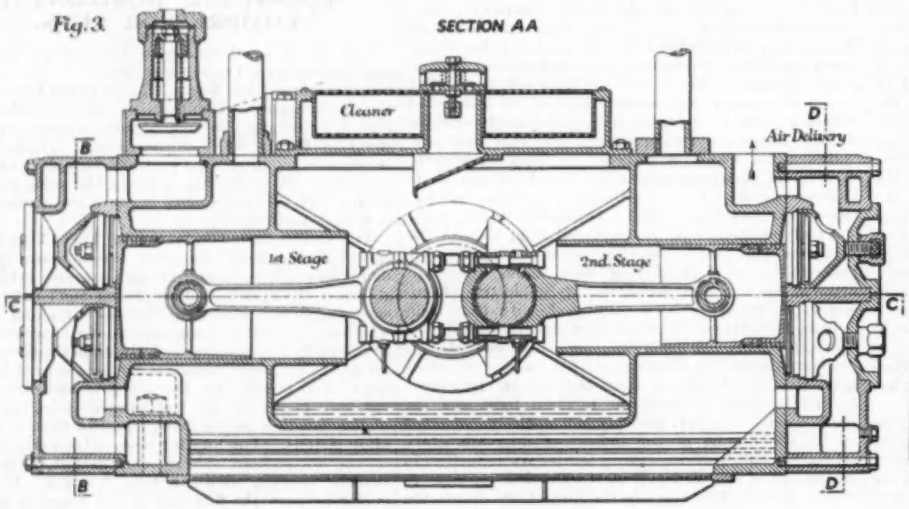


Fig. 4. SECTION BB

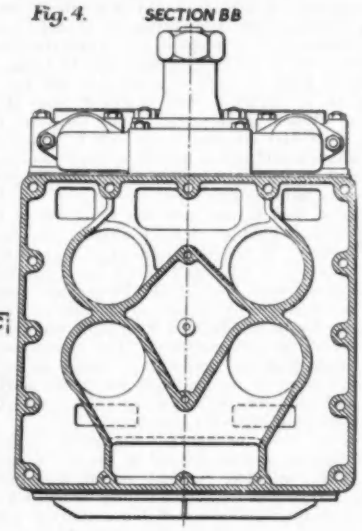


Fig. 5. SECTION CC

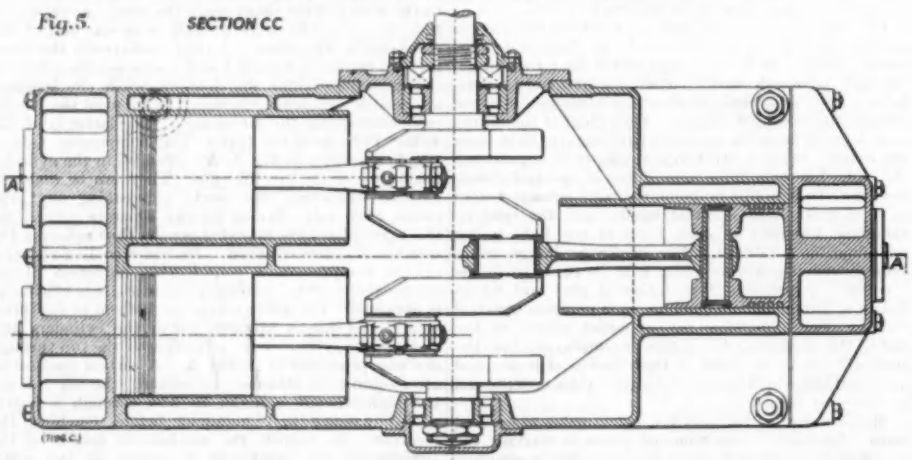
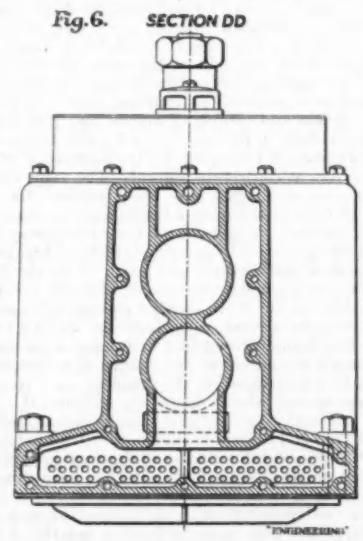


Fig. 6. SECTION DD



grade aluminium alloy. The big-end bearings are lined with white metal, while the small-end bearings are phosphor-bronze bushes locked in place. The high-pressure piston is of "Sesci" iron. All three pistons are fitted with two pressure and two slotted scraper rings. Owing to their high conductivity, the aluminium low-pressure pistons materially assist in cooling the air in the first stage. The cylinder covers are made from the same iron as that used for the firm's oil and gas-engine cylinder covers. Both the water and air passages are large, and the latter are smoothly formed to give a good air flow. The compressor is splash-lubricated from the oil in the sump. As the latter is water-cooled, the splash lubrication assists in cooling the pistons, heat being carried off by the oil thrown back into the sump. The horizontal design ensures that all the working parts get an adequate supply of oil, while the slotted rings prevent any excess of oil from passing into the air spaces. The lubricating-oil consumption is about one pint per 100 running hours.

TWO-STAGE HORIZONTAL COMPRESSOR SETS.

CONSTRUCTED BY MESSRS. THE NATIONAL GAS AND OIL ENGINE COMPANY, LIMITED, ASHTON-UNDER-LYNE.

Fig. 7.

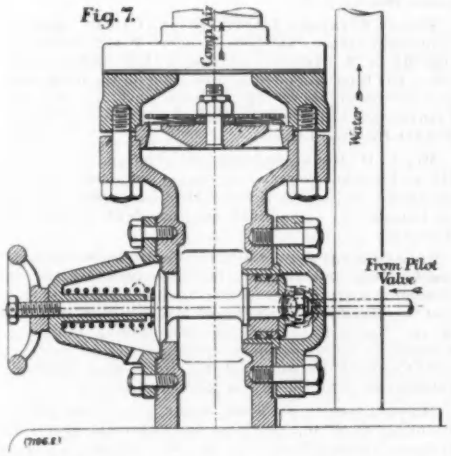
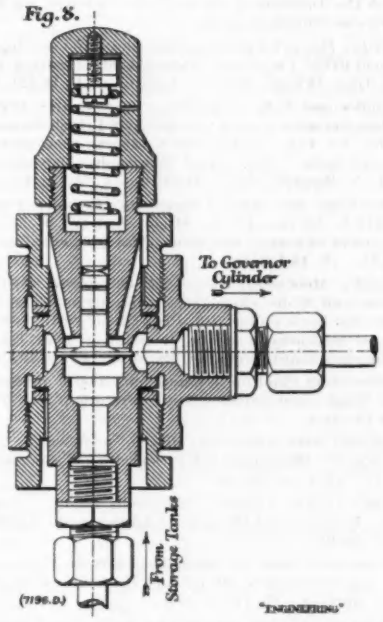


Fig. 8.

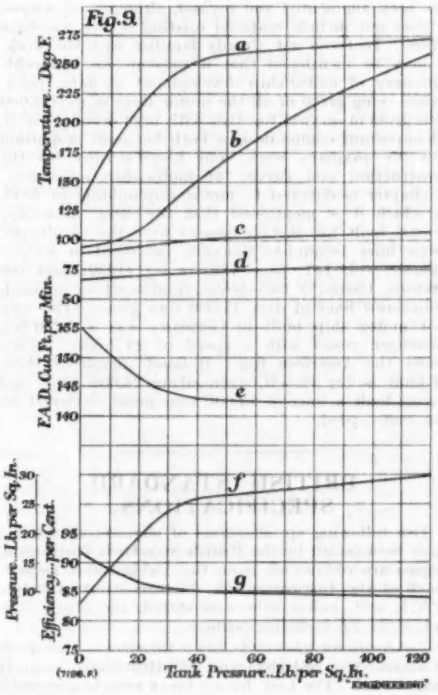


The unloading valve may be arranged in two ways, either to throttle the air inlet to the compressor or to break down the delivery pressure. The former arrangement is illustrated in Fig. 3, the auto-unloader being shown above the low-pressure cylinders. The delivery type of unloading valve is illustrated in Fig. 7, this valve being bolted directly on to the air-delivery port, shown on the right above the high-pressure cylinder in Fig. 3. In both arrangements, a pilot valve, illustrated in Fig. 8, is used to admit air to the operating cylinder of the unloader when the tank pressure reaches the desired figure. The pilot valve, which is identical in the two arrangements, is a low-lift disc valve. In the position shown in Fig. 8, the valve is seated under the spring pressure, the unloader cylinder being open to the atmosphere through the inclined ports shown in the pilot-valve body. As soon as the reservoir pressure rises to the cut-out figure, the valve lifts, closing the atmospheric ports and admitting pressure air to the unloader cylinder, thus unloading the compressor. When the pressure in the reservoir again falls to a figure slightly below the unloading pressure, the valve reseats, cutting off the compressed air supply to the unloader, and at the same time releasing the air in the cylinder to atmosphere. The lift of the pilot valve, which is actually some five-thousandths to ten-thousands of an inch, is carefully proportioned to give a very smart action to the unloader, and the area of the annulus behind each side of the valve is arranged to give the required range between the pressures at which the valve opens and closes.

In the arrangement in which the unloading valve throttles the air inlet, it will be observed from Fig. 3 that the unloader consists simply of a mitre-seated valve, which is located in the manifold between the air cleaner and the compressor inlet port. The valve is operated by means of the piston shown on the valve spindle, the cylinder in which the piston works being connected to the delivery side of the pilot valve. In the alternative arrangement, shown in Fig. 7, the air leaving the compressor first passes through the malleable or high-tensile iron valve casing, and thence through a non-return valve to the storage tanks. There is a spring-loaded valve in the casing, as shown, the spring being strong enough to hold the valve closed up to a pressure 20 per cent. in excess of the normal working pressure. The pilot valve is connected to the cylinder in which the piston mounted on the valve spindle operates, and when the pilot valve comes into action, the unloader valve is moved to the left and the valve is thus lifted, allowing air to escape to atmosphere through the ports shown. Generally speaking, the pilot valve is screwed directly into the unloading valve cylinder. It will be observed that the unloading-valve spindle is provided with a screwed extension engaging with a handwheel, this arrangement enabling the compressor to be unloaded by hand by turning the handwheel, and thus lifting the valve off its seat. It will also be observed that the spring-loaded valve is so arranged that it acts as a relief valve in the delivery pipe should the pressure rise above 20 per cent. in excess of the normal for any reason. It may be mentioned that, when circumstances permit, the makers prefer to install the delivery type of unloader, since, although a compressor with this arrangement uses slightly more power when idling, there is no tendency to suck lubricating oil past the low-pressure pistons, as is the case when the suction-type unloader is employed.

The first-stage cylinders are 5½ in. bore and the second-stage cylinder is 4 11/16 in. bore, the stroke being 5 in. The amount of free air delivered is 140 cub. ft. per minute at a normal working pressure of 100 lb. per square inch. The maximum working pressure is 120 lb. per square inch. The compressor runs at a speed of 1,100 r.p.m., the power required at the clutch being 33 brake horse-power. Performance curves, on a tank pressure base, taken from a radiator-cooled machine, are reproduced in Fig. 9. The three top curves, *a* to *c*, show, respectively, the air temperatures at the first stage, the compressor, and intercooler outlets, while curve *d* shows the air temperature in the shop at the time of the test. Curve *e* shows the free air delivered according to British Standard Specification No. 726 (1937), the volumes being corrected to 60 deg. F. and 30 in. mercury gauge. The intercooler pressure is shown on curve *f*, while the bottom curve *g* shows the volumetric efficiency. The low temperature of the air leaving the intercooler, only 25 deg. above the shop temperature, is particularly noteworthy, together with the high volumetric efficiency for a machine of this size and speed. Another point which may be observed from the curves is that the air temperature leaving the second stage at full output is very nearly the same as that of the air leaving the first stage, showing a good distribution of work between the two stages.

Fig. 9.



The engine is, normally, started by hand, but arrangements may be made for starting by means of a small petrol engine or an air motor employing air from the storage tanks. The clutch coupling the two units is of the centrifugally-operated disc type, adjusted to engage automatically at about half the normal working speed of the compressor. The driven member is integral with the flywheel, and the clutch is totally enclosed in the casing, as shown in Fig. 1. The casing not only protects the mechanism from dirt and grit, but serves to relieve the chassis of all torsional stress. If required, the compressor can be supplied with a hand-operated clutch or with a Sinclair coupling of the fluid-flywheel type. In the two latter cases, the engine is allowed to reach a speed of between 400 r.p.m. and 500 r.p.m. before taking up the compressor drive. Other alternatives are the substitution of one of the firm's high-compression gas engines, or an electric motor, for the Diesel engine, or the compressor can be arranged for belt drive.

In conclusion, some brief particulars may be given of the portable set, illustrated in Fig. 2. The chassis is of deep girder section, fabricated from mild-steel channel sections. The canopy is of mild steel, and, when closed, completely protects all parts of the engine and compressor from the weather. The storage tanks are also enclosed, access to the delivery valves being obtained through a door at the rear of the set. The radiator is fitted with an effective stone guard. The engine silencer is of the Burgess absorptive type, and is carried in the canopy roof. As shown in the illustration, the set is mounted on pneumatic tyres, but iron or solid-rubber tyres can be fitted if required. Internal-expanding brakes are provided in the rear wheels on the model shown, and these may be arranged either for over-run operation or for control from the driver's cab.

ANNUALS AND REFERENCE BOOKS.

A Dictionary of Metals and their Alloys.—The first edition of a little volume, bearing the above title and edited by Mr. F. J. Camm, has recently been published by Messrs. George Newnes, Limited, Tower House, Southampton-street, Strand, London, W.C.2. As its name implies, it deals with the composition and chief characteristics of metals and alloys, and the arrangement is alphabetical. Information is given concerning all the known metals and a wide variety of commercial alloys, these being listed under their trade names as well as under their scientific appellations, adequate cross references being provided. In addition, brief explanations are given regarding such metallurgical and scientific terms as annealing, tempering, age hardening, anodising, Brinell hardness, case-hardening, conductivity, creep, ductility, fatigue, heat treatment, malleability, and recalescence. The information is usually concise and accurate, but we have noted one or two errors; for example, the well-known austenitic 18/8 stainless steel is called Staybrite and not "Staybright," while the name of the Elektron group of magnesium alloys is usually spelt with a "k" and not a "c." At the end of the dictionary portion are a number of chapters on the heat treatment of tool steels; hardening and tempering; metal spraying; electro-plating; the polishing and finishing of metals; and other subjects. The book closes with useful tables of atomic weights, the melting points and other properties of metals, copper-wire data, wire and sheet-metal gauges, and Brinell hardness numbers. The volume, which is well printed and bound, should be of value in the metallurgical laboratory and test room as well as in the works and sales office. The price is 5*s.* net.

The Motor Ship Reference Book for 1940.—Particular interest attaches at the present time to the question of whether our shipowners are tending to rely too much on oil-engined vessels. For the past ten years, the percentage of motor shipping to total tonnage under construction has varied between 45 per cent. and 65 per cent., and as stated in *The Motor Ship Reference Book* for 1940, the figure at the end of the first half of 1939 was 57·5 per cent. Further, as again stated in the reference book, the output of motor shipping in 1939 was, after a period of depression, again up to the record output of 1930 as regards gross tonnage, and the British output was about as much as that for the next two countries combined. After six months of intensive sea warfare, there is every indication that the somewhat depressing prognostications of

those who deplored our increasing reliance on motor ships are unlikely to be fulfilled, but the announcement may be noted that a number of the cargo vessels now being built under the war programme are to be coal burning. The present edition of the reference book under review is the sixteenth, and, as in the past, it has been augmented and revised, although, of course, it does not include material relating to our war-time effort. To those not already familiar with the work, it may be mentioned that it presents an admirable summary of motor-ship development to date, particulars being given of all the motor ships of over 2,000 tons gross in service, together with brief descriptions of all important engine designs both for main propulsion and for auxiliary work, and Lloyd's rules for the construction and survey of motor-ship machinery. A chapter is devoted to motor shipbuilding in 1939, in which it is mentioned that the most important vessels built for British owners were the quadruple-screw liner Dominion Monarch, described in Engineering, vol. 147, page 185, *et seq.* (1939), and the Pretoria Castle, a two-stroke, double-acting engined, twin-screw liner of over 17,000 tons gross. The only fast motor ship built in Germany was a 3,200-ton passenger vessel with a speed of 20 knots, sailing under the American flag. Holland completed three 21-knot motor vessels, aggregating 28,000 tons, and Japan built a liner of 13,000 tons gross, designed for the same speed.

BRITISH STANDARD SPECIFICATIONS.

The following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, and, unless otherwise stated, the price is 2*s.* net, or 2*s.* 2*d.* including postage.

Air-Break Switches and Circuit Breakers.—Two specifications, Nos. 861-1939 and 862-1939, have recently been issued. The first, for air-break switches, includes isolating, totally-enclosed and flame-proof switches for voltages not exceeding 660. Similarly, the second, which concerns air-break circuit breakers, includes those of the totally-enclosed and flame-proof types for voltages not exceeding 660. These specifications combine, in two publications, material originally published in six specifications. Thus, No. 861 covers revisions of specification No. 109-1934, for air-break knife switches, and air-break isolating switches; No. 124-1934, for totally-enclosed, air-break switches; and No. 126-1930, for flame-proof, air-break switches. No. 862 covers revisions of No. 110-1934, for air-break circuit breakers; No. 127-1930, for flame-proof, air-break circuit breakers; and No. 130-1934, for totally-enclosed, air-break circuit breakers. The new specifications, it is felt, will facilitate matters for users, as many of the clauses in the specifications now superseded were common to all of them.

Heavy Aggregates for A.R.P. Shelters.—A revision of BS/ARP No. 1, which specification deals with heavy aggregates for air-raid shelters constructed *in situ*, has now been issued. The scope of the specification has been extended and it now comprises three sections, concerning, respectively, natural aggregates, blast-furnace slag, and crushed brick and tile. The general requirements for all three sections are specified by direct reference to Specification No. 882-1940, for natural aggregates for concrete for structural purposes which specification has itself recently been published (see below). Special requirements are laid down for both the blast-furnace slag and for the crushed brick and tile. [Price 2*d.* net, or 3*d.* post free.]

Natural Aggregates for Concrete.—A new standard, designated No. 882-1940, deals with natural aggregates, up to 1½ in. nominal maximum size, for concrete for structural purposes, including roads. Some of the difficulties of drafting a standard which would adequately cover the wide range of aggregates available, many of them possessing specific characteristics, is referred to in the foreword. This states that considerable research has been necessary in order to safeguard against the possible ruling out of anything which may be satisfactory, and at the same time to ensure that no aggregate would be passed which is unsatisfactory. Much of this work has been carried out by the Road Research Laboratory. The specification may broadly be regarded as falling into two parts. The first covers the general requirements with which all aggregates must comply, and it also includes details of the gradings for aggregates of the various standard sizes. These gradings have been based on a selected series of British Standard sieves with a view to the elimination of unnecessary sizes. The second part of the specification includes appendices which outline the methods of sampling and describe the manner of carrying out the different tests for determining the various properties of the aggregate.

TENDERS.

We have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are as stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

Sensitive Paper, for photostat machines, and developing and acid-fixing *Chemicals*. Department of Survey and Mines, Giza (Orman), Egypt; April 1. (T.Y. 16,721/40.)

Spindles and Bolts, comprising 100,000 N.48 British Standard Spindles, No. 2A; 20,000 N.56 British Standard spindles, No. 13A; and 25,000 N.52 swan-neck, galvanised-steel bolts. Posts and Telegraphs Department, G.P.O., Wellington, N.Z.; April 19. (T. 16,728/40.)

Aluminium and Zinc Lithographic Printing Plates, sizes 116 by 96 cm., 116 by 94 cm., and 108 by 85 cm. Department of Survey and Mines, Giza (Orman), Egypt; April 13. (T. 16,746/40.)

Laundry Machinery, comprising belt-driven washing machine and hydro extractor, an ironing machine and a 20-brake horse-power *Slip-Ring Motor*, with switchgear, for Queenstown Mental Hospital. Union Tender and Supplies Board, Pretoria; March 28. (T. 16,791/40.)

Refrigerating Plant for Johannesburg Police mortuary. Union Tender and Supplies Board, Pretoria; March 28. (T. 16,792/40.)

Pumping Sets, electrically-driven, main-supply and wash-water. Municipal Water Department, Singapore; May 27. (T.Y. 16,797/40.)

Goliath Crane, 15-ton, electrically-driven. South African Railways and Harbours, Johannesburg; April 22. (T. 16,786/40.)

Pressed-Steel Tank, 42,000-gallon, 32 ft. by 8 ft., open top. South African Railways and Harbours, Johannesburg; April 18. (T. 16,787/40.)

Piping and Fittings, required for Table Bay Harbour. South African Railways and Harbours, Johannesburg; April 15. (T. 16,788/40.)

Track-Laying Tractors, two, for the Department of Lands for the Orange River Settlements. Union Tender and Supplies Board, Pretoria; March 21. (T. 16,789/40.)

Transformers, four, 4,000 kVA. three-phase. Municipality of Port Elizabeth, South Africa; April 25. (T. 16,809/40.)

BOOKS RECEIVED.

The Institution of Automobile Engineers. Research Department. Collected Researches on Cylinder Wear. January, 1940. By C. G. Williams, Director of Research, I.A.E. Great West-road, Brentford, Middlesex: Research Department, The Institution of Automobile Engineers. [Price 10*s.*]

The British Journal Photographic Almanac, 1940. Edited by A. J. Dalladay. London: Henry Greenwood and Co., Ltd. [Price 2*s.* 6*d* net.]

R. A. Skelton's Handbook No. 22. Steel Construction and Broad Flange Beams, Grey Process. Moorgate-street Chambers, London, E.C.2: R. A. Skelton and Co., Steel and Engineering, Ltd. [Price 10*s.* net.]

The South and East African Year Book and Guide, 1940. Edited by A. G. Brown. Published for The Union-Castle Steamship Co., Ltd. London: Sampson Low, Marston and Co., Ltd. [Price 2*s.* 6*d.*]

United States Department of the Interior. Bureau of Reclamation. Boulder Canyon Project. Final Reports. Model Tests of Boulder Dam. [Price 2 dols.] Bulletin No. 4. *Stress Studies for Boulder Dam.* [Price 2 dols.] Denver, Colorado, U.S.A.: Offices of the Bureau of Reclamation.

Sell's Directory of Registered Telegraphic Addresses, with Telephone Nos. and Classified Trades, 1940. London: Business Directories, Ltd.

Present Status and Trends of Engineering Education in the United States. A report prepared by Professor D. C. Jackson. 29, West 39th-street, New York City, U.S.A.: Engineers' Council for Professional Development.

United States National Bureau of Standards. Building Materials and Structures. Report BMS31. *Structural Properties of "Insulite" Wall and "Insulite" Partitions Sponsored by The Insulite Co.* By H. L. Whittemore and A. H. Stang, with the collaboration of T. R. C. Wilson. Washington: Superintendent of Documents. [Price 15 cents.]

United States Bureau of Labor Statistics. Serial No. R.1016. *Earnings and Hours in the Meat Packing Industry*, 1937. By J. Perlamn, E. B. Morris and H. O. Rogers. Serial No. R.1033. *Hourly Earning in Knit-Goods Industries (Other Than Hosiery), September*, 1938. By H. E. Riley and J. Perlman. Washington: Superintendent of Documents.

The Motor Ship Reference Book for 1940. Compiled by the Staff of "The Motor Ship." London: Temple Press Ltd. [Price 5*s.* net.]

PERSONAL.

Messrs. Broadway Engineering Company, Limited, Carlisle-road, Hendon, London, N.W.9, have been appointed sole agents for the tool and cutter grinding machine produced by Messrs. Lee and Son, Aberdeen, South Dakota, U.S.A.

Messrs. Standard Telephones and Cables, Limited, Connaught House, Aldwych, London, W.C.2, inform us that Mr. A. W. Hedley, manager of their Bristol branch office, has been promoted to a position on the head-office administration staff. He is succeeded by Mr. W. Litherland, hitherto sales-promotion manager to Messrs. Kolster-Brandes, Limited.

Mr. T. H. Hogg, chairman and chief engineer of the Hydro-Electric Power Commission of Ontario, was installed as the new President of the Engineering Institute of Canada at the annual meeting, held recently in Toronto.

Sir James Lithgow, Bart., the Controller of Merchant Shipbuilding and Repairs, has appointed Mr. S. M. Turnbull, of the Greenock Dockyard Company, Limited, and the Clan Line, Limited, and Mr. Summers Hunter, of the North Eastern Marine Engineering Company, Limited, to be his personal representatives for Scotland and Northern Ireland, and for North-East England, respectively, with the title of Regional Director.

Messrs. Wheatley Kirk, Price and Company are removing from 46, Watling-street, London, E.C.4, to Holborn Viaduct House, 12, Holborn Viaduct, London, E.C.1, on March 19.

Mr. A. P. H. Pehrson has been appointed special manufacturers' representative in the Midlands of Messrs. Simmonds Aerocessories, Limited, Great West-road, Brentford, London.

Messrs. G. A. Harvey and Company (London), Limited, Greenwich Metal Works, London, S.E.7, have now re-opened their West End offices at 58, Victoria-street, S.W.1.

Mr. W. Paterson, district engineer, London Midland and Scottish Railway, Inverness, has been appointed district engineer, Glasgow (Central District), and Mr. I. R. Frazer, assistant to district engineer, Derby (South) has been appointed district engineer, Inverness.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—Production at steel and engineering works having reached such a uniformly high level, the possibilities of further expansion are naturally reduced, but in almost every section conditions are being explored to ascertain whether physical limitations have been reached. Electric-furnace extension is a notable development and more heat-treatment furnaces are being laid down. Practically the whole of the current output of basic steel is going into immediate consumption, while the volume of business passing through engineering works is so great that special-steel production is likely to be mortgaged for many months ahead, despite the basis being broader than ever before in Sheffield's history. The demand for semi-manufactured steel of all types continues at a high level, and the latest descriptions of tool steel find a ready market for war and commercial purposes. The constructional trades report steady progress, but owing to the need to conserve petrol supplies, the distributive trades are making wider use of battery-driven vehicles. Exceptional activity prevails in the tool and implement sections; farming and allotment requirements show a marked rise.

South Yorkshire Coal Trade.—During the past fortnight there has been a marked improvement in deliveries of coal to this district for all purposes. Most industrial concerns are getting all the supplies they need; house coal distributors have wiped off most of the arrears, and are able to pay more attention to current requirements. Pressure on coking descriptions has increased, and there is a steady run on gas coal.

United States Colliery Industry.—The average daily output of bituminous coal in the United States, during the week ending February 24, was 1,650,000 tons, compared with 1,517,000 in the previous week and 1,453,000 tons in the corresponding week of 1939.

Flexible Couplings.—The characteristics of flexible couplings for power-transmission purposes are fully discussed in a new publication issued by Messrs. The Power Plant Company, Limited, West Drayton, Middlesex. While the publication gives particulars of the range of types and sizes of flexible couplings made by this firm, and may, therefore, be classed as a catalogue, it contains much useful information on the principles of installation and design, particularly in the case of the firm's Turbo-type coupling. We understand that copies are now available for users of power transmission equipment.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—New business on the Welsh steam-coal market last week remained curtailed, notwithstanding the fact that demand on both home and foreign account was briskly maintained. The collieries' present outputs were being steadily increased by deliveries made on account of past contract bookings, and there was very little coal available for shipment over the next few months. Most producers had heavy arrears of deliveries to catch up and in several instances outputs were still below the normal levels. As a consequence, the general tone remained very firm. The best feature of the market continued to be presented by the duff coals. Stem lists for these kinds were almost impossible to arrange over several months ahead, and what occasional odd parcels were released through vessels going out of position were eagerly taken up at the recent high figures. Sized and large descriptions were only very sparingly offered for forward shipment, while smalls remained limited. There was an active request circulating for cokes, which, however, were scarce. Patent fuel remained busy.

The Iron and Steel Trade.—Brisk conditions again ruled in the iron and steel and allied trades of South Wales and Monmouthshire last week. Most works remained engaged almost to full capacity, and order books were well filled for some time ahead. The demand for the various products was well maintained.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Heavy demands are now being made on steelmakers for practically all classes of steel material. Order books are so full that there can be no easing off in production for many months and output is being maintained at capacity. New business is very satisfactory, but delivery dates are subject to negotiation, although every consideration is being given to export orders sanctioned by the Government. Structural engineers are taking up a considerable tonnage of material, while the demand for black steel sheets is on a large scale. Makers of sheets have well filled order books and a fair percentage of the orders on hand are on export account. The general inquiry from overseas buyers shows signs of increasing. The following are the current quotations:—Boiler plates, 13*l.* 8*s.* per ton; ship plates, 12*l.* 10*s.* 6*d.* per ton; sections, 12*l.* 8*s.* per ton; medium plates, under $\frac{3}{16}$ in. thick, weighing 6 lb. or more per square foot, 14*l.* per ton, and weighing under 6 lb., but not less than 4·81 lb. per square foot, 14*l.* 10*s.* per ton; black-steel sheets, No. 24 gauge, in 4-ton lots, 17*l.* 10*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, in 4-ton lots, 20*l.* per ton, all delivered at Glasgow stations.

Malleable-Iron Trade.—While the malleable-iron makers of the West of Scotland have a fair amount of work on hand, production has been somewhat slowed down, but is expected to become much better following the publication last week by the Government of the new Iron and Steel (Scrap) Order, No. 7, which raises the price for wrought-iron scrap by 12*s.* 6*d.* per ton. The re-rollers of steel bars continue very busy and are fully occupied, as supplies of semies have been more satisfactory of late. Prices are steady and are as follows:—Crown bars, 12*l.* 17*s.* 6*d.* per ton; No. 3 bars, 12*l.* 10*s.* per ton; No. 4 bars, 12*l.* 15*s.* per ton; and re-rolled steel bars (tested), in 4-ton lots, 14*l.* 3*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—In the Scottish pig-iron trade the position has not altered over the week and the demand continues strong. Consumers of both hematite and basic iron are pressing for deliveries but foundry iron is still quiet. There are fifteen furnaces at present in blast. The following are to-day's market prices:—Hematite, 6*l.* 7*s.* 6*d.* per ton, and basic iron, 5*l.* 4*s.* 6*d.* per ton, both delivered at the steel works; foundry iron, No. 1, 5*l.* 15*s.* per ton, and No. 3, 5*l.* 12*s.* 6*d.* per ton, both on trucks at makers' yards.

COMMITTEE ON NON-FERROUS METALLIC ORES.—The Ministry of Supply has appointed a Departmental Committee to consider whether an increased production of non-ferrous metallic ores in the United Kingdom is desirable and practicable, and to make recommendations. The Committee comprises Sir William Larke, K.B.E. (chairman), Dr. C. G. Cullis, Mr. Arthur Deakin, Mr. J. Stanley Holmes, M.P., and Mr. S. S. Taylor, C.M.G., D.S.O. Professor J. A. S. Ritson, D.S.O., M.I.M.M., Mr. T. Eastwood and Dr. M. Macgregor will act as assessors to the Committee. The secretary, to whom all communications should be addressed, is Mr. W. C. C. Rose, Geological Survey of Great Britain, Exhibition-road, South Kensington, London, S.W.7.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The demand for iron and steel is unabated, and in spite of further increases in the output, producers of some commodities are unable to meet all current requirements. The priority delivery claims continue on so heavy a scale that little tonnage is left for ordinary industrial needs, which are very substantial. Considerable inquiries from overseas are circulating, but sales are limited as export licences are difficult to obtain and home requirements are at a level that precludes the possibility of extensive shipments.

Cleveland Iron Trade.—Fixed prices of Cleveland pig remain at the level of No. 3 quality at 111*s.*, delivered to local buyers, and the figure regulates quotations for the substitute iron for foundry use, production of which is irregular and contributes little to the requirements of consumers. Deliveries of Midland iron to North of England foundry owners, however, is regular and ample. The meagre supply of Cleveland pig causes no uneasiness and little inconvenience.

Hematite.—Conditions in the East Coast hematite branch of trade confine business to narrow limits, but deliveries remain heavy. Most of the large supply is passing into use at makers' own consuming departments, the needs of which are expanding, but buyers are also taking up large quantities. As raw material is in good supply, however, the make could be expeditiously increased by re-kindling idle furnaces. Merchants have command of little iron and producers are anxious to reduce their delivery obligations before entering into new extensive commitments. Stabilised quotations are at the equivalent of No. 1 grade of hematite at 127*s.* 6*d.*, delivered to North of England customers.

Basic Iron.—The present large make of basic iron provides no tonnage for the market, the whole of the output being required for producers' own steelworks.

Foreign Ore.—Consumers of foreign ore have good working stocks and regular imports are larger than recently.

Blast-Furnace Coke.—Transactions in Durham blast-furnace coke are not large or numerous, holders being well sold and local users extensively covered. Good medium qualities are put at 31*s.* 8*d.* at the ovens.

Manufactured Iron and Steel.—Imports of Continental semi-finished iron and steel are steadily maintained, and, together with the substantial local make, provide re-rollers with tonnage that fully meets requirements. In the finished industries, works are very busily employed, the only exception being the light-casting department, which is adversely affected by the position of the building trade. Sheet makers have contracts to execute that ensure the full activity of their plant over several months, and producers of shipbuilding requisites have well-filled order books.

Scrap.—The recently advanced maximum prices for iron and steel scrap are readily realised for all available parcels. There is still some shortage, but the supplies of one or two descriptions are less scarce.

PANAMA CANAL TRAFFIC.—During the year ending November 30, 1939, 5,948 vessels, carrying 29,094,579 tons of cargo, passed through the Panama Canal, compared with 5,556 vessels and 25,899,043 tons of cargo in the preceding twelve months.

OXFORD MANAGEMENT CONFERENCE.—The 42nd Oxford Management Conference is to be held at Lady Margaret Hall on April 5. The Conference is organised by the Confederation of Management Associations, 5, Pierrepont-street, Bath, and we understand that a private conference was held in Oxford, at the beginning of the year, to prepare the ground for the forthcoming one. This will be a plenary meeting, and will include a programme of public addresses.

THE CONTROL OF ALUMINIUM.—The Ministry of Supply has made arrangements with the British Aluminium Company, Limited, and the Aluminium Company of Canada for substantial increases in the output of aluminium in the United Kingdom and Canada. *The Board of Trade Journal* states that, in Canada, the increase in output is sufficient to make the total capacity of the Dominion alone almost equal to that of Germany. The two companies, moreover, have undertaken to co-operate with the Ministry in developing any further increases in capacity which may be required. The Ministry has also purchased the entire output of the British Aluminium Company for 1940 and of the Aluminium Company of Canada for the remainder of 1940 and the whole of 1941, less only that required for consumption in Canada, and for fulfilling certain pre-war commitments. Basic prices approximately equal to those current in the United Kingdom and Canada before the war have been agreed.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTE OF MARINE ENGINEERS.—To-day, 12 noon, Connaught Rooms, Great Queen-street, Kingsway, W.C.2. Annual General Meeting and Luncheon.

INSTITUTION OF ELECTRICAL ENGINEERS.—To-night, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Informal Meeting. Discussion on (i) "Cathode-Ray and Duddell Type Oscillographs—Advantages and Disadvantages for Audio-Frequencies," to be opened by Professor J. T. MacGregor-Morris. (ii) "What Are the Practical Limits of Error in A.C. House Service Meters and in Sub-Standard Watt Meters?" to be opened by Mr. A. J. Pitt. *Mersey and North Wales (Liverpool) Centre:* Monday, March 18, 6.15 p.m., Quaintways Café, Northgate-street, Chester. (i) "Development of a Pre-Stressed ('Toughened') Glass Insulator," by Mr. P. M. Hogg. (ii) "Performance of Glass Insulators and Comparisons with Porcelain," E.R.A. Report, to be presented by Mr. C. E. R. Bruce and Dr. S. Whitehead. *Sheffield Sub-Centre:* Wednesday, March 20, 6 p.m., King's Head Hotel, Sheffield. Discussion on "Electrical Testing of Steels."

INSTITUTION OF MECHANICAL ENGINEERS.—To-night, 6 p.m., Storey's-gate, Westminster, S.W.1. General Meeting. Thomas Lowe Gray Lecture: "Fifty Years of Marine Engineering," by Professor A. L. Mellanby. *Yorkshire Branch:* Saturday, March 16, 2.30 p.m., The Technical College, Bradford. Lecture: "Vibrations in Machinery," by Mr. W. A. Tuplin.

JUNIOR INSTITUTION OF ENGINEERS.—*Midland Section:* Saturday, March 16, 2.30 p.m., James Watt Memorial Institute, Birmingham. "Industrial Power and Heating," by Mr. R. L. Kirlew.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Yorkshire Branch:* Saturday, March 16, 2.30 p.m., Hotel Metropole, Leeds. "Bridges in the West Riding," by Mr. H. A. Whitaker.

INSTITUTION OF PRODUCTION ENGINEERS.—*Yorkshire Section:* Saturday, March 16, 2.30 p.m., Hotel Metropole, Leeds. Lecture: "Progress in Machine Tool Design," by Mr. R. C. Fenton. *Manchester Section:* Monday, March 18, 7.30 p.m., The College of Technology, Manchester. Lecture: "The Collection and Control of Factory Oncosts," by Mr. T. G. Rose. *Birmingham Section:* Wednesday, March 20, 7 p.m., James Watt Memorial Institute, Birmingham. Lecture: "Thread Grinding and Gauging," by Mr. S. J. Harley.

INSTITUTION OF AUTOMOBILE ENGINEERS.—*Glasgow Centre:* Monday, March 18, 7.30 p.m., Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. "Exhaust Systems for Four- and Six-Cylinder Engines," by Dr. J. C. Morrison. *Birmingham Centre:* Tuesday, March 19, 7 p.m., James Watt Memorial Institute, Birmingham. Joint Meeting with THE INSTITUTE OF METALS and THE IRON AND STEEL INSTITUTE. Symposium on "Deep-Drawing Research," by Professors H. W. Swift, J. H. Andrew and C. A. Edwards. *Coventry Graduates' Branch:* Tuesday, March 19, 7.15 p.m., The Broadgate Café, Coventry. "Developments in Hydraulic Braking," by Mr. J. C. Smith. *London Graduates' Branch:* Thursday, March 21, 7.15 p.m., 12, Hobart-place, S.W.1. "Production Organisation," by Mr. D. H. Bramley.

SOUTH WALES INSTITUTE OF ENGINEERS.—Tuesday, March 19, 3.15 p.m., Institute Buildings, Park-place, Cardiff. Thirteenth William Menelaus Memorial Lecture: "Electricity as Applied to Metallurgy," by Dr. A. P. M. Fleming.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 19, 5.30 p.m., Great George-street, S.W.1. "The Sewage Disposal of Delhi," by Mr. J. A. R. Bromage. *North-Western Association:* Wednesday, March 20, 6.15 p.m., 36, George-street, Manchester. "The Treatment of Water by Ozone," by Mr. M. T. B. Whitson.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—Tuesday, March 19, 6.30 p.m., Lighting Service Bureau, 2, Savoy-hill, W.C.2. Lecture: "Electricity as Applied to Coal Mining Underground," by Mr. D. M. Rait.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Middlesbrough Branch:* Saturday, March 23, 3 p.m., Cleveland Technical Institution, Middlesbrough. Annual General Meeting. Short paper competition.

NEW ROLLING STOCK FOR THE LIVERPOOL AND SOUTHPORT LINE, L.M.S.R.: ADDENDUM.—In the description of the new rolling stock for the Liverpool and Southport services of the L.M.S. Railway, which appeared on page 222, *ante*, the statement was made that Messrs. The English Electric Company, Limited, were the contractors for the electrical equipment. We are informed, however, that this contract did not include the air-compressor motors, which were manufactured by Messrs. Bull Motors (Branch of E. R. and F. Turner, Limited), Ipswich.

LA MONT WASTE-HEAT BOILER IN M.S. "HAV".

(For Description, see Page 275).

Fig. 1.

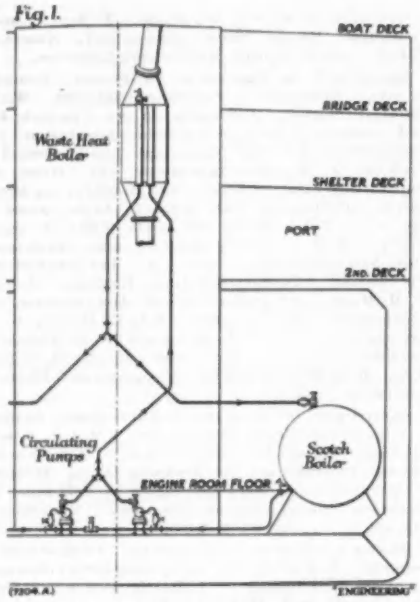


Fig. 2.

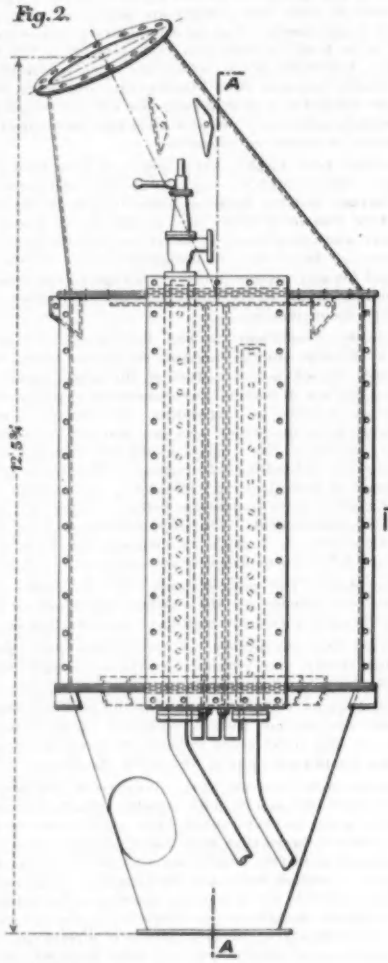


Fig. 3. SECTION AA

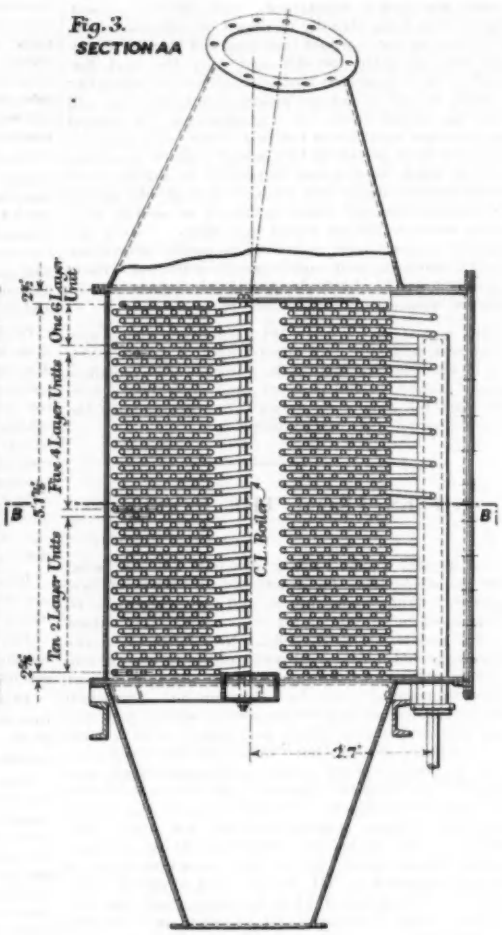


Fig. 4.

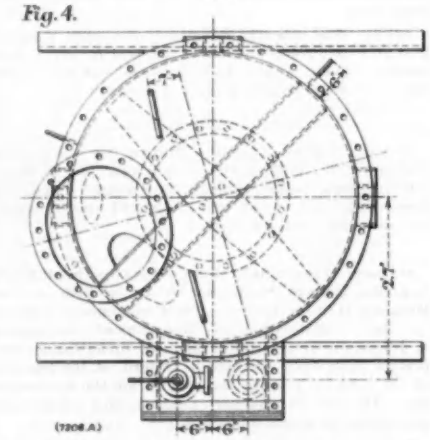
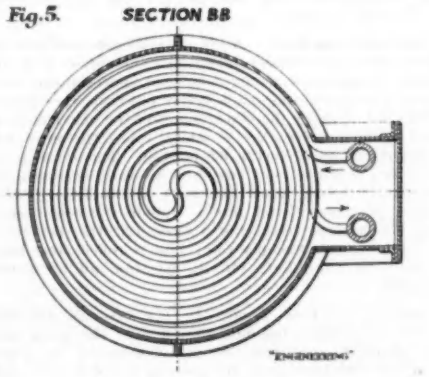


Fig. 5. SECTION BB



THE PROPERTIES AND USES OF INCONEL.

THE main characteristics of the nickel-chromium-iron ternary alloys are considerable strength and resistance to oxidation at high temperatures, coupled with a high degree of resistance to numerous corrosive substances. In point of fact, it was mainly for the purpose of resisting attack and tarnishing by food products that the alloy Inconel, which contains approximately 80 per cent. of nickel, from 12 per cent. to 14 per cent. of chromium, and from 6 per cent. to 8 per cent. of iron, was originally developed. The chromium content makes the alloy superior to pure nickel under oxidising conditions and also enables it to offer a high resistance when exposed to sulphur compounds in the atmosphere or in other corrosives. The high-nickel content, on the other hand, provides considerable resistance to corrosion by inorganic and organic compounds under reducing conditions and also to attack by alkaline solutions. The fact that the material is capable of withstanding attacks by a wide range of corrosive products has caused it to be selected for varied purposes in industry, in addition to its original applications in food and beverage processing. The resistance of Inconel to deterioration at elevated temperatures has led to some important applications, including springs exposed to high steam temperatures, containers employed in the nitriding industry and anchor bolts for refractories in marine boilers.

A comprehensive account of the properties, typical uses, and fabrication characteristics of Inconel is contained in a brochure issued recently by Messrs. Henry Wiggin and Company, Limited, Thames House, Millbank, London, S.W.1. It is stated therein that the material possesses good workability both in the hot and in the cold. The fabrication of the annealed alloy, it is pointed out, is facilitated by reasonably low yield-strength values of 11 tons to 18 tons per square inch, with elongations of from 55 per cent. to 35 per cent. in 2 in.

Tensile strengths as high as 83 tons per square inch are obtainable in heavily cold-worked wire, while satisfactory castings can also be produced, typical mechanical properties of which are given as :—Ultimate strength, 32 tons per square inch ; yield point, 18 tons per square inch ; elongation on 2 in., 10 per cent. to 15 per cent. ; and Brinell hardness, 160. In the form of cold-drawn rod, cold-rolled sheet and strip, and hard-drawn tubing, the Brinell hardness of the alloy ranges from 220 to 250 ; after annealing, the hardness value becomes 130 to 150. The endurance limits, in air, for hot-rolled and cold-drawn bar, determined on single specimens in each case, have been found to be 16 tons and 20 tons per square inch, respectively, while fully-annealed material has given an air endurance limit of 14·5 tons per square inch. The results of a limited number of creep tests indicate that the maximum stresses which do not cause an increase in length of the test specimens of more than 0·1 per cent. during a continuous test of 10,000 hours, are 14 tons per square inch at 480 deg. C., 11 tons at 510 deg. C., and 8 tons at 540 deg. C. Impact tests, made on hot-rolled Inconel specimens, using a Charpy machine, it is stated, have given results averaging approximately 200 ft.-lb. Furthermore, even with energy-absorption values of this high order, the specimens did not fracture. The alloy is claimed to possess far better spring properties than other materials of comparable corrosion resistance, it being stated that springs made of Inconel are used frequently at temperatures of 400 deg. C. As already indicated, the alloy is readily workable ; forging, the hot and cold-rolling of sheet and strip, and the hot rolling and cold-drawing of rods being conducted in a manner similar to that obtaining in steel practice. Moreover, all the standard joining methods, such as lock seaming, riveting, bolting, soldering, silver soldering, brazing and welding, by the metallic-arc, oxy-acetylene and resistance-welding methods, are available. In common with most high-grade alloys, precautions are necessary in machining operations, but, provided the instructions prescribed are followed, the machining of the alloy appears to offer no difficulty.

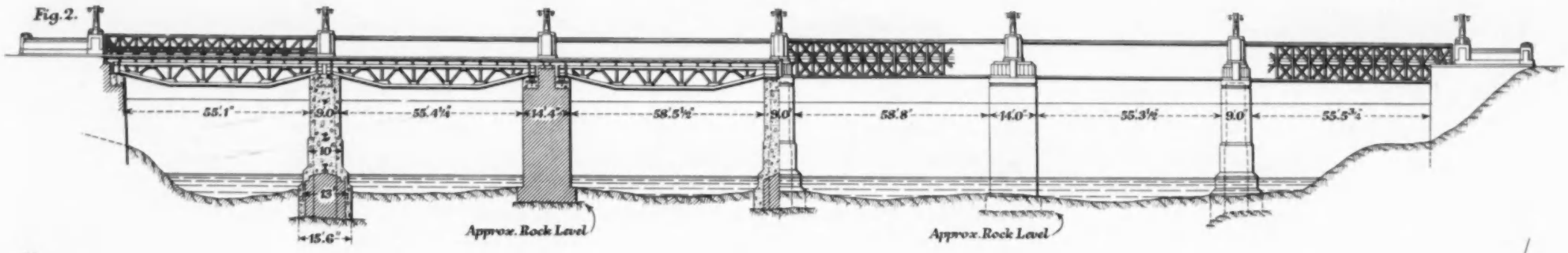
ROYAL NATIONAL LIFE-BOAT INSTITUTION.—From the foundation of the Royal National Life-Boat Institution in 1824 until December 31, 1939, the total number of lives rescued was 67,506.

THE CENTENARY OF BARON DE PRONY.—We gave, on page 83 of our last volume, an account of the life and work of Baron de Prony (1755-1839), the eminent French civil engineer. In 1801, Prony became a member of the first Council of the Société d'Encouragement pour l'Industrie Nationale, and this body organised a special meeting to celebrate the centenary of his death. The date was originally fixed for the autumn of 1939, but the meeting had to be postponed on account of the war, and we have just learned that it is being held to-morrow afternoon, Saturday, March 16, in the house of the Société in the Rue de Rennes, Paris. Addresses on Prony's life and many-sided activities are to be delivered by Mr. Walckenaer, Professor Montell and other prominent French engineers.

RECONSTRUCTION OF THE KATUGASTOTA BRIDGE, CENTRAL PROVINCE, CEYLON.

(For Description, see Page 269.)

Fig. 2.



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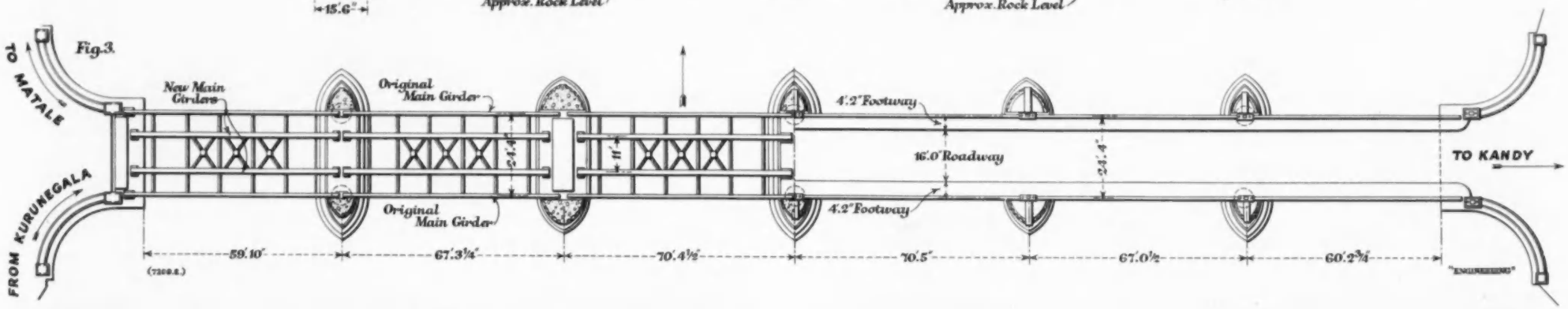

Fig. 4. Kandy End Pier, Showing Flood Plates Before Removal.

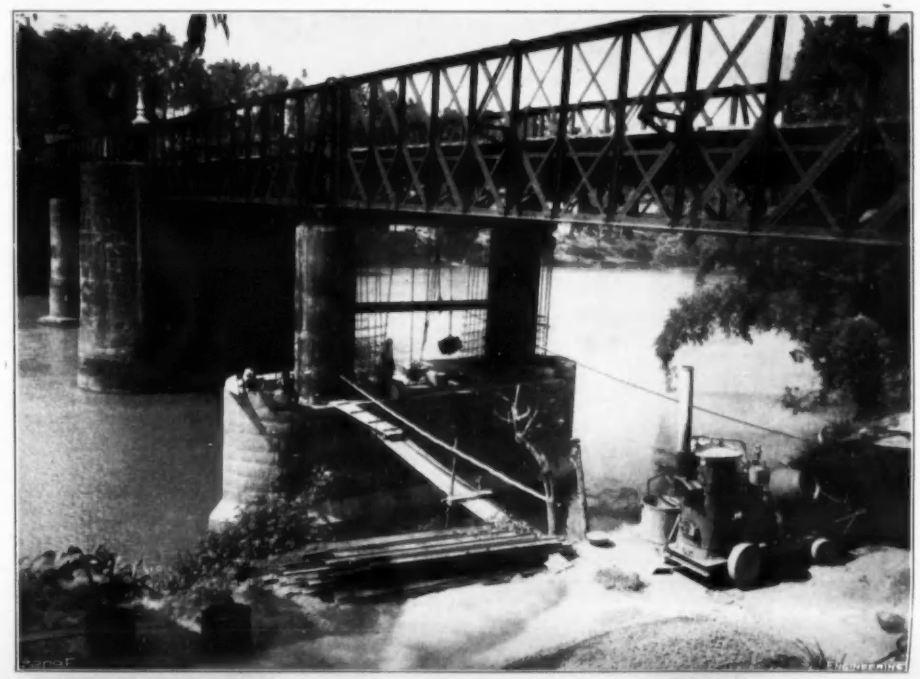

Fig. 5. Kandy End Pier: Masonry Facing in Progress.

Fig. 4. Kandy End Pier, Showing Flood Plates Before Removal.

Fig. 5. Kandy End Pier; Masonry Facing in Progress.

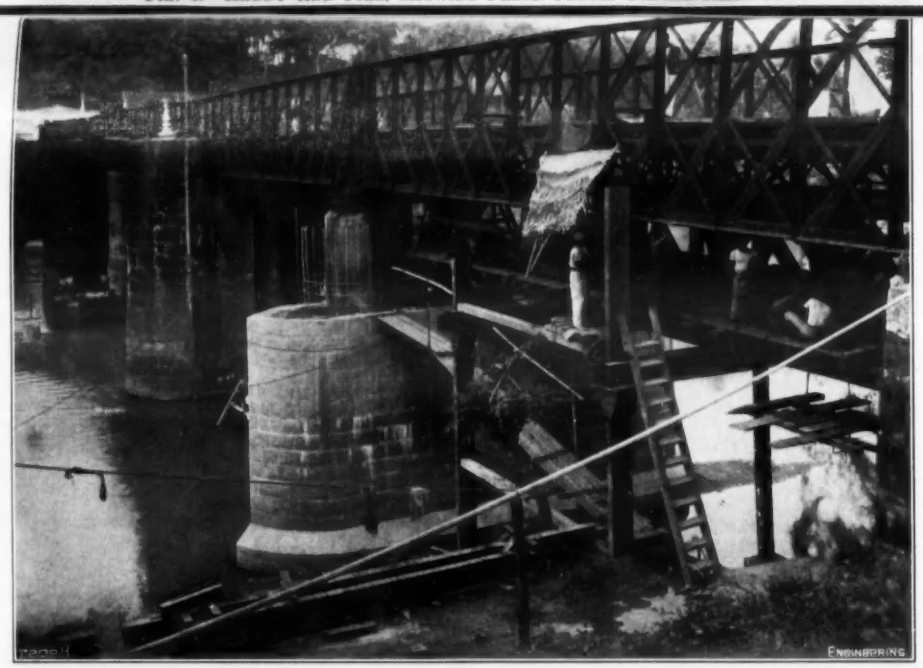

Fig. 6. Matale End Pier; New Under Girder Being Erected.

Fig. 7. Cofferdam Round Matale End Pier.

Fig. 8. Cofferdam Round Central Pier; Excavation in Progress.

Fig. 9. Central Pier, Showing Concrete Delivery Arrangements.

ENGINEERING.

Offices for Publication and Advertisements, 35 & 36, Bedford Street, Strand, London, W.C.2.

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Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of Publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

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TEMPORARY ADDRESS.

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ENGINEERING

FRIDAY, MARCH 15, 1940.

VOL. 149. No. 3870.

BRITISH SHIPPING AND THE WAR.

THE annual report of the Chamber of Shipping of the United Kingdom, always a valued indication of the position and prospects of this most vital of British industries, acquires a new significance after six months of war. The freight situation, immediately prior to the outbreak of hostilities, was less favourable than it had been for a couple of years, as judged by the weighted index based on the standard year, 1929; and the outlook for owners of tramp tonnage would have been still less attractive, but for the considerable quantities of grain and other essential commodities, bought on Government behalf by the Ministry of Supply. Some idea of the extent of these operations was given on January 11, by Colonel J. J. Llewellin, M.P., and reported on page 67, *ante*. It may be supposed that these Government purchases under the National Defence programme were largely responsible for the increase in the number of fixtures from the River Plate from 161 in the first eight months of 1938 to 498 in the corresponding period in 1939. Although the latter total seems, by comparison, to presage a return to normal prosperity, it was still a long way short of the 746 fixtures, British and foreign, recorded in the first eight months of 1937. This gives a truer picture of the amount of leeway requiring to be made good.

It will be recalled that, prior to the outbreak of the war, freights in the principal shipping markets were controlled by the various minimum-freight schemes. The British Shipping (Assistance) Bill, 1939, envisaged a continuance of these schemes, at least until 1945, but this Bill had not reached its third reading when hostilities commenced, and the system of freight co-operation naturally lapsed. According to the Chamber of Shipping report, however, the machinery of this co-operation is being retained with a view to a resumption of this or some similar scheme when peace and normal trading are again restored. So far as British shipping is concerned, freight rates are now fixed by the Government, and, although some increases in the controlled rates have been found inevitable, the return to the shipowners is still on a scale which leaves little margin for depreciation and replacement, while the prices of new ships, as well as running costs, have already shown considerable increases. In this connection, some striking figures are adduced by the Chamber. In April, when the Government proposals for assistance to shipping were being considered, it was shown that the running costs of deep-sea tramps were about 25 per cent. above the level of 1935, and they have since risen very materially. The average running costs of liners in January, 1940, were about 25 per cent. in advance of pre-war figures, and must be expected to increase further in the immediate future. Building costs are now about 60 per cent. higher than the prices ruling two years ago.

These figures, which cannot be regarded as final, do not offer any encouraging hope for the financial prosperity of either tramp or liner companies, on the basis of past earnings, and without making any allowance for possible further increases in taxation and operating expenses. The published accounts of 28 liner companies for 1938 and 1939, covering a paid-up capital totalling nearly 60,000,000*l.*, and reserves of about 28,000,000*l.*, show that only 5,700,000*l.* was put aside for depreciation in 1939, as compared with 7,300,000*l.* in 1938 and 5,000,000*l.* in 1937. This proportion, as the report points out, barely covers the current depreciation, and contributes nothing to reduce the heavy arrears of depreciation which accumulated during the prolonged depression. The average dividend paid in 1939 was 4·2 per cent. on the paid-up capital, or 2·84 per cent. on the aggregate of capital and reserves, the corresponding figures for 1938 being 4·79 per cent. and 3·28 per cent., respectively.

The position of the tramp companies, which do not enjoy the same comparatively assured level of business as the liners, is even less satisfactory, although, on a basis of published dividends alone, it appears at first sight to be slightly more favourable. The average of published dividends in 1939 was 5·5 per cent., an increase of about ½ per cent. above the yearly average taken over the whole period since the last war; but, between 1920 and 1938, only about half of the normal and necessary allowance for depreciation could be met out of earnings, and during the six years, 1930 to 1935, the arrears of depreciation in the tramp-shipping industry amounted to more than 10,000,000*l.* After allowing for the temporary recovery experienced since the last-mentioned date, it is calculated that British tramp shipping still has about 7,500,000*l.* of these arrears to make good. It will be seen, therefore, that British owners, especially of ships in the tramp category, entered the war with a considerable financial handicap, the effect of which has not been lessened by the circumstances that their possible war-time earnings are strictly limited, while the relative position of their foreign competitors has been improved by the increased demand for cargo tonnage. Not only are the neutral owners able to command higher rates of freight, and so to build up substantial reserves to meet the inevitable difficulties of immediate post-war trading, but the withdrawal, for war purposes, of many British ships from their normal trade routes permits and encourages the transfer of such trade to neutrals, from whom it will not be readily recovered.

At the outbreak of the war, the Government put into operation the scheme of war-risk insurance previously agreed, and they have since put forward additional proposals designed to retain in the industry, for replacement purposes, the increased values which may accrue to owners under the original insurance scheme; but, as the Chamber of Shipping report emphasises, this scheme is limited in scope to the replacement of ships lost by war casualty, and does not touch the major problem of replacing vessels removed from the register by ordinary marine casualty or by obsolescence.

Various estimates indicate that more than a million tons of new shipping must be built annually to maintain the British mercantile marine at even the depleted figure of its pre-war tonnage total.

At the present time every shipbuilding berth that can be manned in this country is fully occupied, and is likely to remain so while hostilities last. The ships are being built on Government account and will be Government property, but it is improbable that the advocates of State shipowning will prevail against the weight of evidence that shipping is not a suitable form of national trading in time of peace, and it may be regarded as inevitable, therefore, that this great fleet of merchant ships will be disposed of at the earliest opportunity, when the occasion for unified control ceases to be paramount. As we have remarked before, no standardised type of ship can be uniformly the most successful in all the manifold special conditions which govern the world's carrying trade in particular waters; the most that can be expected is an average degree of general suitability. It is possible, therefore, that the owners who acquire these ships, as a quicker means of reconstituting their fleets than that of ordering more specialised craft and waiting for them to be built, will seek to dispose of this standard tonnage after a comparatively short period, thus substantially repeating the experiences of the years which followed the last war. In any case, it is evident that British shipowners are likely to encounter difficulties in re-establishing their trade connections.

It is to be hoped that the Government's advisers will recognise this probability in good time, and will not needlessly handicap the industry in its forthcoming struggle by imposing financial and legislative burdens and restrictions, which, however seemingly desirable at the present juncture, cannot be regarded as essential to its efficient functioning.

THE CONTROL AND SALVAGE OF PAPER.

When, in 1858, Lord Elgin went as Queen Victoria's ambassador to the Emperor of Japan, on the visit which marks the beginning of British trade with that country, his entourage were astonished at the consumption of paper by the Japanese, especially by those in official positions. They trusted to memory for nothing; everything had to be written down; and, to ensure the accuracy of the recorded impressions, they were taken down by two independent reporters, whose accounts were subsequently compared. Yet, as was observed at the time by the captain of His Excellency's steam frigate, the procedure was no more complicated than the method of ordering stores in the Royal Navy, which then required the names of twelve witnesses whenever a purchase was made, and, the papers being in triplicate, six-and-thirty signatures. Since those backward days, the consumption of paper for public, domestic, military and commercial purposes has expanded beyond the wildest dreams of eighty or even thirty years ago. The stages in the development need not be traced in detail. The trend was obvious at the time of the Boer War, when rapid duplicating processes (apart from direct printing) were relatively in their infancy. The spread of form-filling in the Services was strikingly demonstrated in 1915, when the minelayer Princess Irene blew up at Sheerness, and showers of paper descended upon the outskirts of Maidstone, more than 15 miles away. The immense increase in the use of wrapping papers during the last decade, to look no farther back, requires no emphasis, and the supersession of tins and wooden boxes by cardboard packages is a tendency to which the last war gave great encouragement.

The extent of the demands which the present-day consumption of paper and paper products make upon sea transport was indicated by Mr. A. Ralph Reed, Paper Controller in the Ministry of Supply, in a statement made on February 15 and summarised in our issue of February 23. The total consumption during 1938, Mr. Reed then said, amounted to about 3¼ million tons, of which almost exactly one-third was imported. In common with other journals, we have since received from Mr. Reed a further appeal for co-operation in bringing home to the public the very real necessity for a more stringent economy in the use of paper—a need which, he states, "has already been strongly urged upon all the principal consumer trades and Government Departments." This is a request, to the broad principle of which we are glad to lend support, especially in its application to the excessive multiplication of wrappers, so noticeable in recent years in connection with many mass-produced proprietary articles. The more extensive organisation of waste-paper collection, now in process of development, should lead to the recovery of an effective proportion of the annual consumption of newsprint and other printing papers, but paper wrappings are not so conveniently preserved and observation suggests that the possible percentage of salvage in this field is materially less.

In any campaign of this kind, however, the most beneficial result must involve a compromise between the outwardly obvious course of action and that which a more careful examination of the problem may demonstrate to be preferable; and in this respect it is difficult to endorse unreservedly some of the suggestions put forward by the Paper Controller. Some such doubt appears to exist in his own mind, for he admits, with reference to the use of paper for wrapping and packing manufactured goods and foodstuffs, that "there is certainly no cheaper alternative form of packing nor one which makes less demand upon the national resources or import facilities." An example of another kind may serve to emphasise the same point. We receive a considerable number of notices, pamphlets and other pronouncements from certain Government Departments, the subject-matter of which bears no conceivable relation to the interests of this journal or of the majority of its readers. It would be easy to stigmatise this regular distribution of unwanted printed matter as a sheer waste, regarding it only in relation to the paper consumption that it represents; but with these irrelevant leaflets come others which it is necessary that we should have, and it requires little reflection to appreciate that the labour of pre-selecting only those which concern a particular periodical would make wholly unjustifiable demands upon the staff and organisation of any Ministry. The economic factor must be the ruling consideration if the maximum benefit is to accrue to the nation as a whole; but, applying this criterion to the departments in general, perhaps it is permissible to suggest that some of these communications are less essential to the public weal than their sponsors evidently believe.

The problems of salvage call for circumspection equally with those of control, although in this case the responsibility is not so much that of any Government department as of the individual owner of presumptive waste material. Sir Wilfrid Greene, the Master of the Rolls, has issued a warning, through the British Records Association, against any such indiscriminate destruction of old records as took place in the last war, when it was found that many irreplaceable documents, of considerable historical value, were pulped for want of an informed opinion of their worth. Early records of technical achievements, especially those associated with commercial undertakings, are even more exposed to such risks than are legal and sociological archives. An inquiry, some years ago, regarding some tests of an experimental gun, carried out at Woolwich Arsenal on the application of a private inventor, revealed that practically no records relating to the operations of the Arsenal itself now remain of earlier date than the beginning of the present century, when a clean sweep was made of all earlier correspondence, drawings, etc., at the command of one unappreciative official, acting, apparently, on his own responsibility. Similar purges have taken place in many old-established engineering works in recent years and, as the market price of waste paper rises, are increasingly liable to recur. We would urge upon the executive heads of such firms, therefore, the desirability of inviting the opinion of the Director of the Science Museum, South Kensington, or of the secretaries of the Newcomen Society, 43, King's-road, Chelsea, S.W.3, before entering upon the destruction of papers of actual or potential historical value as records of technical and scientific progress.

NOTES.

Anglo-French Industrial Agreement.

The full agreements which have been reached between the British and French Governments on the dual questions of the supply of everything which concerns the military effort of the Allies, and of reciprocal trade between the two countries, have recently been supplemented by an important scheme of co-operation, which has been jointly inaugurated by the Confédération Générale du Patronat Français and the Federation of British Industries. The ultimate aim of the collaboration between these two bodies is to conduct the export trade of Great Britain and France so as to ensure a fair return for producers with full regard to consumers' interests. With this end in view, agreements are to be promoted between individual industries in the two countries, so that uneconomic competition, will be eliminated and so that a price level which will ensure the development of consumption in the respective export markets, shall be maintained. It is hoped that this co-operation will be permanent and, in order that the export trade may be developed, they are prepared to recommend to their respective Governments that in suitable cases productive capacity at present allotted to armaments in one country should be released for export trade by the importation of armaments from the other country. It is also agreed that, during the war, imports should be obtained from their respective countries rather than from third countries. Competition in the purchase of raw materials should also be eliminated. The two delegations have decided to constitute themselves into a permanent Anglo-French Industrial Council which will maintain and develop the relations established by the agreement. The first task of this body will be to investigate the extent to which individual industries in France and Great Britain are in a position to enter into negotiations on matters of common interest and to arrange for such negotiations. In this connection endeavours will be made to promote agreement between complementary as well as like industries, while the extension of economic and financial collaboration between the two Empires will also be considered. As regards post-war economic policy, it is considered that the common objective must be the rapid establishment and expansion of international trade and that this result will be better achieved by co-operation than competition. Finally, the desire is expressed that other countries will participate in this policy.

Evacuation and Electricity Supply.

The adverse effect of evacuation, both official and unofficial, and of the blackout, on the fortunes of the electricity supply companies which operate in London, was disclosed by Mr. George Balfour, M.P., at the annual general meeting of the Metropolitan Electric Supply Company recently. In the Paddington and mid-London areas served by this undertaking the increase in output was 8·1 per cent. during the first half of 1939, compared with the corresponding period in 1938. In spite of reductions in price, there was also a 4·3 per cent. increase in revenue. On the other hand, during the second half of the year, when the increase in output is usually larger, there was a decrease of 21 per cent. in consumption and of 13·7 per cent. in revenue. The Notting Hill area discloses an even more serious result. Here, during the first half-year, the consumption increased by over 10 per cent., though there was a decrease of 1·3 per cent. in revenue owing to the reduction in tariffs, but in the second half the decrease in consumption was no less than 25·7 per cent. and the decrease in revenue 20 per cent. The consumption during November and December decreased by over 40 per cent. and the bulk supply showed a decrease of 17 per cent. on the normal of anticipated demand. The number of consumers at the end of December was 213,376, or 2,800 less than at the end of 1938, while, of the consumers connected, some 10,000 who might be described as well-to-do have ceased to be "live." A similar story was told by Mr. Oliver Bury at the annual general meeting of the London Electric Supply Corporation. The output of this company, he said, had fallen to 380,100,577 kWh, a decrease

of 4,455,417 kWh compared with 1938, although an increase of some 9 per cent. had been recorded up to the end of September. The position is doubly unfortunate for the shareholders, since a policy of tariff-reduction had recently been entered into with the certainty that some falling off in revenue might be temporarily experienced, but in the hope that this would be speedily counteracted by an increased consumption. The war has, of course, upset these otherwise justifiable calculations.

Vierendeel Welded Bridges in Belgium.

It will be remembered that after the collapse, on March 14, 1938, of the Vierendeel welded bridge which crossed the Albert Canal at Hasselt, a technical commission was set up by the Belgian Government to investigate the cause of the disaster. This matter was referred to in the Chamber of Representatives on February 1, when M. Montagne, the Minister of Public Works, stated that this Commission had not yet presented a definite report. He said that, after the accident at Hasselt, the other welded bridges over the canal had been subjected to close inspection and investigation. Various defects had been brought to light and the necessary repair and reinforcement work had been carried out. On January 16 of this year, cracks were discovered in some of the members of the Herenthals-Oolen bridge over the canal. This bridge, which carries a tramway, was one of those which had previously undergone repair. In view of the new defects which had been discovered, the bridge was being underpinned, and would not be re-opened for public traffic until this work was completed. A few days later, on January 22, cracks occurred in a number of places on the Kaulille bridge, over the Meuse-Scheldt Canal. This is one of a group of eight Vierendeel welded bridges which were constructed simultaneously. They were thought to be in entirely satisfactory condition, but would have been subjected to detail inspection after the completion of the similar work on the Albert Canal bridges. The cracks in both the Herenthals-Oolen and Kaulille bridges made their appearance at times of intense cold and sudden changes of temperature. In concluding his statement, M. Montagne said that the whole situation was rather alarming, bearing as it did on every one of the numerous welded bridges over the Albert and Kempen canals, and would remain so until technical referees could give a definite opinion about the cause of the various failures.

The Jubilee of the British Corporation.

The 1940 annual meeting of the British Corporation Register of Shipping and Aircraft, which was held at the head office, 14, Blythswood-square, Glasgow, on Wednesday, March 6, was an occasion of particular note in that it marked the completion of 50 years of the society's operations. The progress achieved during that period was the principal theme of the speech made by the chairman, Mr. Gilbert J. Innes, who recalled that the British Corporation originated in 1890 as the result of a belief, held by various Clydeside shipbuilders and shipowners, that existing rules for ship construction had not kept pace with progress in materials and their advantageous utilisation, so that owners were dispensing with classification and were building ships to suit their own requirements. The decision of the Government, in the same year, to introduce load-line legislation changed the situation, but the inclusion of the Corporation among the recognised load-line authorities enabled its new strength standards to be put into practice. The effect was well shown in the first cargo vessels, of about 10,000 tons displacement, constructed to the Corporation Rules, the saving in hull weight being some 300 tons by comparison with previous standards, and the potential earning capacity correspondingly increased. From the beginning, the Articles of Association provided that no one interest should acquire excessive influence, and gave builders, engineers, underwriters and other technical representatives an equal share with shipowners in the management of the society. This element in the constitution, it appeared from the early records, was suggested by the Board of Trade. The first ship built under the Corporation's special survey was the cargo steamer Turret, the initial ship of the new type which became generally known by her name. Other well-known vessels which figured in the Register included the Loongana, the first ocean-going turbine steamer; the pioneer motorship, Jutlandia, which was the first Diesel-engined vessel to cross the Atlantic; and the Allan liners Victorian and Virginian, the comparative performances of which contributed materially to the establishment of the steam turbine for ship propulsion. The connection of the Corporation with aircraft dates from 1927, when an organisation was established for the inspection of civil machines. Subsequently, the Government created the Air Registration Board to undertake these duties, modelling its constitution on that of the Corporation and appointing Sir Maurice Denny as chairman.

Payment for Duplicate Grid Supplies.

The standard tariff under which the Central Electricity Board supplies energy wholesale to the distributing undertakings consists, generally speaking, of three parts, namely, a service charge in respect of each point of connection to the Grid; a fixed annual kilowatt charge based on the maximum demand at each point of connection; and a running charge for each kilowatt-hour supplied. In practice, however, no service charge is made for the first point of supply and it has not, therefore, usually given rise to controversy. Recently, however, it has come into some prominence, partly due to the desire of the retail undertakings to guard against breakdowns in cases such as those at Bradford and Kingston-on-Thames, where occurrences in generating stations led to a more or less prolonged cessation of the supply at a time when it was badly needed. Undertakings have sought, therefore, to obtain another point of supply, for use in emergency or otherwise, and the terms upon which this is to be paid for have recently been the subject of representation by the Incorporated Municipal Electrical Association to the Central Electricity Board. Without going too deeply into the question, it may be pointed out that, where the second point is treated as entirely separate and paid for at the appropriate grid tariff, owners of selected stations, who, by the Electricity (Supply) Act, 1926, are entitled to be given a supply on terms not less favourable than that at which they could generate for themselves, are placed at a disadvantage. Undertakings, too, which take a supply at the grid tariff, also lose the benefits of diversity and of the reduced charge which is made per kilowatt of demand as that demand increases. Consequently, it has been argued that the charge for a second point should only be made when the Board has, as a result, incurred considerable capital expenditure. On the other hand, the tapping of a line for such a purpose may result in it being impossible to utilise fully the remaining length for the purpose of connecting two existing grid points. Fortunately, it would seem that a compromise has been reached, the Board having agreed that, where the second point is required solely for use in an emergency involving interruption at the first point, it will give sympathetic consideration to the suggestion of waiving the charge. Where, however, the second point is needed to deal with the undertaking's normal requirements and, incidentally, to save distribution expenditure, it appears that the charge will continue to be demanded. This arrangement appears to give a substantial measure of justice to both parties.

The South Australian Railways.

With another great war urging road as well as air transportation towards unpredictable states of perfection, there must be some uncertainty about the future of railway development in so vast and relatively "new" a country as Australia. That competition by road operators is already an obstacle to profitable working is brought out clearly in the annual report of the South Australian Railways Commissioner for the year ended August 31, 1939. This shows a financial deficit on the year of 232,106*l*., bringing the total deficit up to 1,011,844*l*. Abnormally low wheat prices, by restricting sales and consequently the carriage of this commodity, reduced railway earnings by an estimated 140,000*l*.; and subsequent diminished purchasing power of the community, combined with the unstable international situation, caused a further loss of 69,000*l*. in returns from the carriage of general merchandise. Wages expenditure was raised by 53,000*l*. a year under awards made by the Commonwealth Arbitration Court. Increased coal prices cost a further 20,000*l*. In such ways, working expenses have grown from last year's 83·6 per cent. to 90·1 per cent. of this year's total revenue of 3,133,373*l*. Preliminary charges on proposed railways have been written off and no new track laying has been undertaken. Six 2-8-4 type locomotives have been constructed, together with 50 sheep vans, 57 bogie ore wagons, and 21 miscellaneous vehicles. Seventeen boilers have been constructed in the railway shops. A viceregal car, 24 steel passenger cars, 95 sheep vans, 12 bogie louvre vans and 63 bogie ore wagons were under construction at the end of the financial year. All side-loading passenger coaches and brake vans are being fitted with automatic couplers. A new train-control circuit has been introduced to bring more traffic under the Adelaide control staff, and other circuits have been extended. Wheat traffic totalled only 527,155 tons this year, a fall of 208,227 tons from last year's figure, and now takes second place in the list of principal freight items after mineral ore and concentrates, of which 657,207 tons were carried an average distance of 244·73 miles. Freights earned by ores, wheat, livestock (mainly sheep and cattle), and wool, amounted, respectively, to 492,031*l*., 276,894*l*., 209,160*l*., and 78,807*l*. Passenger traffic produced 600,383*l*., an increase of 29,614*l*. on the previous year's receipts. Although much of its mileage lies in sparsely-populated country districts, the railway derives most of its passenger receipts from a relatively well-populated metropolitan area centring upon Adelaide. Of the 17½ million passenger journeys made in the year, 16¼ millions were suburban journeys of an average distance of 7·04 miles. It is worthy of note that, throughout the year, there were no train accidents and no passenger fatalities.

THE INSTITUTE OF METALS.

The thirty-second annual general meeting of the Institute of Metals was held at the offices of the Institute, 4, Grosvenor-gardens, London, S.W.1, on the afternoon of Wednesday, March 6. At the opening of the meeting, which was chiefly of a formal character, no papers being presented or discussed, the chair was occupied by the President, Dr. C. H. Desch, F.R.S.

Report of the Council.

The report of the Council, which concerned the proceedings and work of the Institute during the year ending December 31, 1939, was the first matter to be considered after the minutes of the previous meeting had been dealt with. This showed that the members on the roll numbered 2,337, as compared with 2,252 on December 31, 1938, and 2,166 on December 31, 1937. The total membership of 2,337, it was pointed out, was the highest on record. The outbreak of the war had naturally affected the activities of the Institute, and the local sections had been forced to curtail their autumn programmes, but every effort was being made to maintain the work of the Institute with the greatest possible efficiency. New arrangements for the publications had been made which, while lessening the burden on the finances, would not deprive members of any of the papers or abstracts to which they were entitled. The library and information services had been maintained, and in this respect the co-operation with the Iron and Steel Institute, begun last year, had proved very successful in practice. The Council had to record, with deep regret, the deaths of a number of members, among whom were Engineer Vice-Admiral Sir Henry J. Oram, K.C.B., F.R.S. (a Past-President), Mr. G. Bill-Gozzard, Mr. T. G. Hirst, Vice-Admiral Sir Robert B. Dixon (Vice-President), Professor H. M. Boylston, Mr. W. A. Cowan, Dr. K. Erdmann, Professor H. Fay, Mr. J. E. Fletcher, Mr. F. C. A. H. Lantsberry, Professor H. Louis, and Mr. J. W. W. Willstrop. The first three gentlemen had been original members of the Institute. After the outbreak of the war many members had been allocated to work of national importance under various Government Departments through the Central

Register for National Service of the Ministry of Labour. In the compilation of the Register the Institute had co-operated with the Ministry for several months before the outbreak of hostilities. The large volume of correspondence with members, regarding the Register, indicated their keen desire to be of service in this time of national emergency.

Honorary Treasurer's Report.

The report prepared by the honorary treasurer of the Institute, Mr. John Fry, who has now retired from that post after 16 years' service, was next considered. This indicated that the income for the year ending June 30, 1939, amounted to 7,290*l.* and the expenditure to 7,572*l.*, thus showing an excess of expenditure over income of 282*l.* Comparison of the income with that of the previous year showed that annual subscriptions had increased by 136*l.* and interest on War Loan by 266*l.* On the expenditure side, however, owing largely to the occupation of the Institute's new headquarters, there were many increases, which, with higher expenses in connection with the library, meetings, printing, repairs and renewals, etc., amounted in all, to 1,201*l.* Moreover, a contribution of 200*l.* had been made towards the expenses of organising the American Meeting, originally planned for the autumn of 1938 and later postponed. The donations received towards the Endowment Fund totalled 15,370*l.*, and, adding to this sum donations due under covenant or otherwise promised, the total became 19,358*l.* When opportunities were more favourable, the Council hoped to increase this fund. The "Silver Jubilee" Fund, amounting to 672*l.*, and the House Fund, totalling 1,228*l.*, had been transferred to a new general reserve fund in the balance sheet. After presenting his report, Mr. Fry thanked the Council for having conferred upon him, at their last meeting, the honour of Fellowship of the Institute.

Election of Officers.

The officers nominated by the Council at the statutory autumn meeting, held in London, on November 16, 1939, were declared to be duly elected for the year 1940-41, namely, as President, Lieut.-Col. The Hon. R. M. Preston, D.S.O.; as vice-presidents, Dr. S. F. Dorey, Engineer Vice-Admiral Sir George Preece, K.C.B., and Mr. A. J. G. Smout; as honorary treasurer, Lieut-General Sir J. Ronald E. Charles, K.C.B., D.S.O.; and as members of the Council, Dr. W. E. Alkins, Mr. G. L. Bailey, Mr. F. C. Braby, Colonel P. G. J. Gueterbock, D.S.O., and Professor D. Hanson.

Institute of Metals Medal.

The President then announced that the Institute of Metals Medal Committee had met and had considered possible candidates for the award of the Platinum Medal. Their unanimous decision had been that the Medal should, this year, be presented to Dr. Paul D. Merica, whose scientific work in the United States was of great value to metallurgists throughout the world. Dr. Merica had sent a cable expressing his thanks for the great honour which had been conferred upon him and stating that he would endeavour to come to Europe as soon as opportunity offered in order to receive the Medal.

Induction of New President.

At this stage of the proceedings the retiring President, Dr. C. H. Desch, inducted the President-elect, Lieut.-Col. The Hon. R. M. Preston, D.S.O., into the chair. In doing so, Dr. Desch stated that the office of President was normally occupied, in turn, by representatives of non-ferrous metal producers, users, and academic scientists or research workers. It had not always been possible to adhere strictly to this practice of alternation, but a consideration of the list of past-presidents of the Institute would show that it contained the names of many leading figures in each of these three callings. The incoming President was a producer; after a distinguished military career, he had entered industry and now, among others, occupied the position of managing director of the Rio Tinto Company, Limited.

On taking the chair, Colonel Preston said that after giving the matter a good deal of thought, he had come to the conclusion that a long address would be inappropriate in the present circumstances. Most of the members were engaged, directly or indirectly, in some work in furtherance of the national effort, and were more than ordinarily occupied and pressed for time. He proposed, therefore, to say only a few words on this occasion, reserving a longer address for next year. This procedure had been adopted on more than one occasion by previous Presidents. His two predecessors in the chair, Dr. Desch and the late Mr. W. R. Barclay, were original members of the Institute, and both had been connected, directly or indirectly, with non-ferrous metals research during most of their working lives, whereas he had first come into intimate contact with the industry some fifteen years ago. He hoped, however, that he would be able to make some contribution, on certain lines, towards the growth and prosperity of the Institute and would have something to say on this subject if he were in the chair at the annual general meeting in 1941.

A few words might now be said regarding the work of the Institute during the war. Members would have read, in the report, the decision of the Council to restrict, in some degree, the Institute's publications, as a matter of economy. On the other hand, it was satisfactory to be in a position to announce that members were not to be deprived of the May Lecture as had, at one time, been thought likely; and that the local sections were continuing their meetings. Financial economy had been forced upon the Institute, but economy of thought was not to be contemplated. The financial position, though strong, was not without its weak points, as had been pointed out by the honorary treasurer, and the loss of membership, due directly to the war, connoted a substantial reduction in income in the immediate future. The active membership had been reduced by 140 members, who were either Germans or Poles. There was, perhaps, comfort in the thought that, during the war of 1914-18, despite the loss of many Central European members, the numbers on the roll increased, between 1914 and 1919, from 645 to 1,213, but he did not thing that the Institute could count on a comparable increase at the present time. Much could be done, however, by the efforts of individual members. While increase of membership was at all times desirable, he believed that members should give their first thoughts at present to the Endowment Fund inaugurated by the late Mr. Barclay. In spite of the difficulties which lay ahead, it was his hope and belief that the Institute would emerge at the end of the war stronger, more authoritative, and more representative than ever before.

After a vote of thanks to the retiring President had been proposed by Dr. H. Moore, seconded by Dr. R. Seligman, and carried with acclamation, Col. Preston announced that a general meeting of the Institute would be held on Wednesday, May 8. The afternoon would be devoted to the discussion of certain papers which had appeared in the *Journal*, while, in the evening, the May Lecture, on "The Cyclotron and Its Applications," would be delivered by Professor J. D. Cockcroft, F.R.S. The meeting, he added, was naturally conditional on the war situation allowing it to be held.

"Smokeless Air."—It would be a matter of serious concern to the community if interest in the activities of the National Smoke Abatement Society were allowed to lapse under present conditions, and the Society does well in continuing to publish its journal, *Smokeless Air*, the Wartime Issue No. 2, of which is now available. This issue contains useful comments on the first instalment of a report by Miss Marion Fitzgerald on the cost of smoke as it affects the maintenance of multiple shops, banks, hotels and so forth, the distribution of which over the country enables reliable estimates to be made of the cost entailed by situation in a smoky area as compared with a comparatively clean one. A paper on Atmospheric Pollution by Mr. James Law, is given in abstract, and the difficult problem of smoke emission from colliery power plant is dealt with. A new publication, by the Smoke Prevention Association of the United States, is reviewed. In addition to the journal, a special leaflet entitled *Smoke Abatement in Wartime* is issued by the Society, and is worthy of attention at the present time.

LETTER TO THE EDITOR.

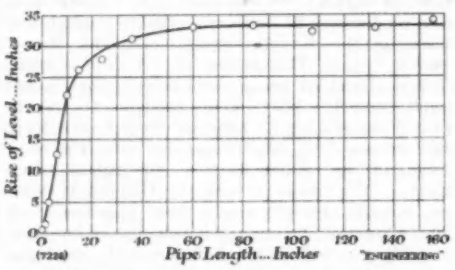
THE KADENACY SYSTEM OF SCAVENGING.

To the Editor of Engineering.

Sir,—I trust you will allow me space to give the results of some further experiments carried out following the publication in your issue for February 2 of the letter by Mr. S. G. Bauer on the above subject.

In a previous* letter, I described tests made with an apparatus similar to that used by Mr. Bauer, except that the cylinder was 13 in. long and 4 in. in diameter. A sensitive non-return valve was fitted at the lower end of the cylinder and was connected to a vertical glass tube dipping into coloured water. Discharge occurred on the bursting of Cellophane sheets either through a plain 2½-in. orifice or through a 2-in. orifice connected to pipes of varying length. In the latter case, the discharge caused a marked suction through the non-return valve, the effect being clearly noticeable even with the pipe length reduced to 3 in. With the plain orifice there was no sign of any suction effect.

In the above experiments a cylinder having a comparatively large ratio of length to diameter was purposely chosen since it appeared to me that such proportions should favour the production of the "Kadenacy effect." In view of the results obtained by Mr. Bauer, however, it was decided to repeat the tests using a much shorter cylinder. The length of the cylinder was, therefore, reduced to 3 in. (the diameter being 4 in.). The non-return valve was again used as an indicator in preference to the method adopted by Mr. Bauer, as some doubt was felt as to the possibility of covering the orifice sufficiently quickly to avoid



contamination of the cylinder contents owing to the intense turbulence in the cylinder following discharge.

Tests with a discharge pressure of 40 lb. to 45 lb. per square inch (gauge) showed a rise of level in the tube connected to the non-return valve of approximately ½ in., using a plain 2½-in. orifice, and of approximately ¼ in. with a 2-in. orifice of the type used by Mr. Bauer. These results corroborate those obtained by Mr. Bauer in showing that a suction effect may be produced when discharge occurs through a plain orifice.

The accompanying graph shows the observed rise of level in the suction tube when discharge occurred through pipes of $\frac{33}{32}$-in. diameter and of varying length. The rise of level does not, of course, give a quantitative measure of either the magnitude of the depression occurring in the cylinder or of its duration, but I submit that it does afford a very good comparison of the net useful suction effect. In view of the overwhelming influence of the exhaust pipe on the effective suction, there seems every justification for the conclusion that the production of any appreciable depression following discharge is an exhaust pipe effect, dependent on the conservation of the kinetic energy of the issuant gases by use of a pipe or duct. In this connection, I would point out that both in my previous letter and in the conclusions drawn in my original† article, my contention was that "the production of any appreciable vacuum in the cylinder following exhaust is only possible where some form of exhaust pipe or duct is fitted." The words "appreciable vacuum" were intended to refer to a depression of sufficient magnitude and duration as to be effective for scavenging purposes in an engine cylinder, and were used advisedly, for the following reason:—I have contended that the depression produced when discharge occurs through an exhaust pipe is due to the return of the negative reflection of the primary pulse of pressure. It is known that reflection does not take place from the open end of the pipe, but from a point slightly beyond the end, and since when no pipe is fitted a short jet is still formed it seemed not unlikely that some relatively insignificant depression should arise from the same cause.

Yours faithfully,

Graham F. Mucklow.

Engineering Department,
University of Manchester. March 7, 1940.

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* Engineering, vol. 148, page 589 (1939).

† Engineering, vol. 148, page 189 (1939).

THE LATE DR. R. T. GUNTHER.

THE history of science has lost an enthusiastic worker and exponent by the death of Dr. Robert Theodore Gunther, on March 9. Dr. Gunther, who became University Reader in the History of Science at Oxford in 1934, was the first curator of the Lewis Evans collection of ancient scientific instruments, this latter post dating from 1924. In 1922, Dr. Lewis Evans offered his fine collection of old scientific instruments to the University of Oxford, stipulating only that it should be housed in an appropriate manner. By a happy chance, owing to the removal of the geological and physical specimens to the Clarendon Building in 1832, and of the archæological collections to the University Galleries in 1894, space was available in the old Ashmolean Museum and the Lewis Evans' collection was accordingly there housed, in an entirely fitting way. Dr. Gunther entered, with enthusiasm, on the task of arranging the collection, and greatly added to it by the rescue of material from the obscurity of various college libraries and by purchase. A valuable gift of early telescopes and surveying instruments was made by the Royal Astronomical Society in 1931. The measure of the success of Dr. Gunther's work may be judged from the illustrated description of the collection which we published in 1933.*

Dr. Gunther, who was born in 1869, was the son of Dr. Albert Günther, F.R.S. He was educated at University College, London, and Magdalen College, Oxford, where he obtained a first class in Natural Science. He was a biological student at Naples in 1893 and an Oxford Geographical student in 1895. He then became a tutor at Magdalen College and was later Curator of the Oxford Botanic Garden and Library of Magdalen College. In addition to his knowledge of early physics, he was an authority on the archæology of many branches of science and his historical writings extended to geological, geographical, and biological subjects. He was, however, particularly interested in early scientific instruments and mathematical apparatus, and was probably the greatest authority of his time on the astrolabe. He was of charming personality and those to whom he exhibited the beloved instruments of which he had charge could not fail to catch some of his enthusiasm. His publications included *Early Science in Oxford ; Historic Instruments for the Advancement of Science ; The Great Astrolabe and Scientific Instruments of Humfrey Cole ; The Life and Work of Robert Hooke ; The Astrolabes of the World ;* and many others dealing with related subjects.

CREEP AT HIGH TEMPERATURES.†

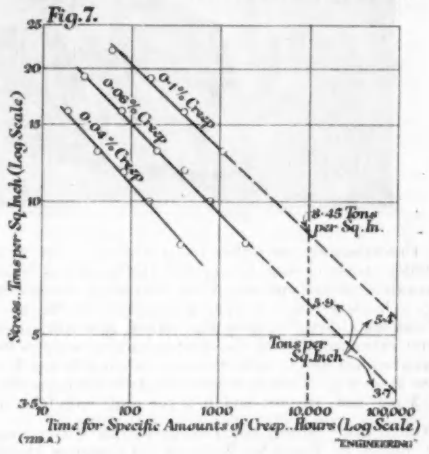
By H. J. TAPSELL, A.C.G.I.

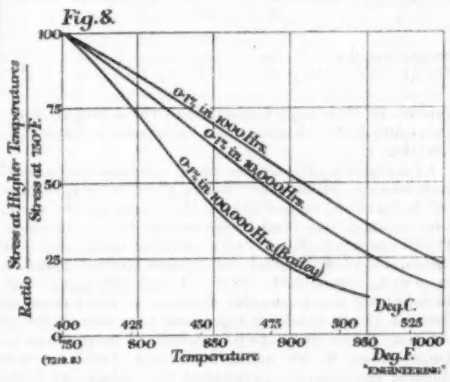
THE author has had considerable experience of the differences in creep properties occurring among steels of similar composition, especially carbon steels. Numerous carbon steels containing between 0·15 per cent. and 0·42 per cent. carbon have been compared as regards their resistance to creep at 450 deg. C. (842 deg. F.) under a stress of 8 tons per square inch, and results in illustration of their variability are given in Table V. All the steels were tested in the normalised condition in which the microstructure shows ferrite with pearlite usually well defined. The values given represent the maximum variations found in the steels, some of which were not manufactured specifically for high-temperature use.

TABLE V.—*Variation in Creep Properties of Carbon Steels.*

Carbon Content.	Process.	Creep Rate at 5 Days. Temperature : 450 deg. C. Stress : 8 tons per sq. in.
Per cent.		In. per in. per hr.
0·16	Acid open hearth	1·0 × 10⁻⁶
0·19	,, ,,	22·5 × 10⁻⁶
0·23	,, ,,	0·5 × 10⁻⁶
0·24	,, ,,	2·5 × 10⁻⁶
0·13	Basic electric	3·3 × 10⁻⁶
0·16	Basic open hearth	2·0 × 10⁻⁶
0·16	,, ,,	140·0 × 10⁻⁶
0·25	,, ,,	2·5 × 10⁻⁶
0·20	,, ,,	46·0 × 10⁻⁶
0·40	Acid open hearth	3·0 × 10⁻⁶
0·42	,, ,,	7·4 × 10⁻⁶
0·40	Basic electric	21·0 × 10⁻⁶

From the data in Table V it is evident that it is possible to obtain carbon steels of relatively poor creep resistance manufactured by any one of the three processes. While the above test data were being accumulated, an investigation of the causes of poor creep resistance was receiving attention, and it is believed that much less variation in creep properties should be met in the future in regard to steels specially manufactured to render them suitable for high-temperature service. Table V illustrates another factor of importance, namely, that as good creep resistance at 450 deg. C. is obtainable for 0·16 per cent. carbon steels as for 0·25 per cent. or 0·4 per cent. carbon steels. Tests at other temperatures have been made on steels selected from those described, and have shown that the steels of poor creep resistance at 450 deg. C. are poor and at 400 deg. C. and at 550 deg. C., and also at lower stresses than 8 tons per square inch. The tensile properties of the steels at air temperature provide no evidence of weakness at high temperatures, and the tensile properties at high temperatures are not satisfactory as a criterion of creep resistance. The creep rate is the most discerning measure of the effect of very small differences in the constitution and structural condition of two very similar steels, so that differences in creep rates in the ratio, say, 2 : 1, mean little difference in strength ;





a small change in stress, or slight difference in temperature in the case of one steel would bring its creep rate into line with the other.

In recent years, research has been made into the possibilities of improving carbon steels by the addition of small quantities of alloying elements, and molybdenum appears to be the most effective single addition. Molybdenum steel containing about 0·5 per cent. to 0·8 per cent. molybdenum is finding use in steam-power plant operating at 900 deg. F. and above. Its creep strength much exceeds that of carbon steel ; in other respects, it has much the same properties as carbon steel. A comparison of four wrought molybdenum steels, each containing about 0·5 per cent. molybdenum, on the basis of the creep rate at 500 hours for a stress of 9 tons per square inch at 550 deg. C. (1,022 deg. F.), is given in Table VI. All the steels were made in high-frequency electric furnaces, and were tested in the normalised condition. The results given in Table VI for molybdenum steels may be compared with those in Table V for carbon steels which were tested at a temperature 100 deg. C. lower.

Creep tests on the molybdenum steels at other stresses than 9 tons per square inch have been made and show the same sort of variation among the four steels as recorded in Table VI, but the examination of a larger number of steels would be necessary to determine whether or not the variations shown are representative. However, from these and other tests, it appears that low carbon is advantageous in both 0·5 per cent. and 1 per cent. molybdenum steels, and that 0·8 per cent. or 1 per cent. molybdenum gives somewhat better results than 0·5 per cent. The addition of a small percentage of vanadium to molybdenum steel appears to produce further improvement in creep properties ; molybdenum-vanadium steels of different composition are now being studied by the author. Some chromium-molybdenum steels have similar good strength at high temperatures to the plain molybdenum steels and have the advantage of better resistance to oxidation and corrosion. Steels containing about 6 per cent. chromium with about 0·6 per cent. molybdenum have very good resistance to corrosion, but have less resistance to creep than those in which the chromium is about 0·8 per cent. to 1 per cent. In the hardened and tempered condition, molybdenum-containing steels are used as bolt materials for high-temperature bolted connections.

The condition of a metal at the time it is put into service has to be considered in relation to its subsequent behaviour ; the strength properties change more often than not during service, and the initial state has a bearing on the rate of change. Referring specifically to carbon and molybdenum steels, a structural alteration involving a change in the carbide from the lamellar to the spheroidised form is brought about by prolonged heating, which change is rapid at 1,050 deg. F. but very slow at 800 deg. F. The rate of change is affected by the initial condition of the steel ; an annealed

TABLE VI.—*Comparative Creep Rates of Four Molybdenum Steels.*

Steel.		Creep Rate at 500 hours. Stress : 9 tons per sq. in. Temperature 550 deg. C.
Carbon.	Molybdenum.	
Per cent.	Per cent.	In. per in. per hr.
0·11	0·52	6·8 × 10⁻⁶
0·185	0·50	1·1 × 10⁻⁶
0·16	0·62	0·4 × 10⁻⁶
0·40	0·55	7·3 × 10⁻⁶

cast steel is usually more difficult to spheroidise than a normalised wrought steel, but a cold-rolled steel is usually more rapidly spheroidised. Results for 0·10 per cent. to 0·15 per cent. carbon steels show that, at the higher temperatures now being adopted in steam plant, normalised material can be raised to a temperature about 35 deg. F. above that for spheroidised material for the same rate of creep ; alternatively, the use of material in the spheroidised condition necessitates a reduction in operating temperature by 35 deg. F. In the case of 0·4 per cent. carbon steel, the equivalent temperature difference is about 50 deg. F. The influence of carbide spheroidisation is at least as important in the case of molybdenum steels. Partial spheroidisation of a wrought 0·11 per cent. carbon 0·52 per cent. molybdenum steel by heating it at 625 deg. C. (1,155 deg. F.) for fourteen days caused marked deterioration ; compared with the same steel in the oil-quenched and tempered condition, its creep rate at 550 deg. C. (1,022 deg. F.) for a stress of 9 tons per square inch, was 80 times as fast. A feature of interest and value in the case of molybdenum steel is that heating during service at moderately high temperatures of the order 800 deg. F to 900 deg. F. produces some improvement in creep resistance. Even at 1,000 deg. F., the first effect is an improvement lasting several months and it is only after a protracted period that spheroidisation causes a decline in creep properties.

At moderate superheat temperatures, cast carbon and molybdenum steels are inferior to the wrought steels, but this inferiority decreases as the temperature increases, and there is little to choose between the two states at about 1,000 deg. F. Grain size has an influence on the creep properties of a steel, and it has generally been supposed that large grain size is an advantage. A 0·4 per cent. carbon steel coarsened by heating at 1,100 deg. C. before normalising showed an improvement in creep properties at 450 deg. C. (842 deg. F.) as compared with its properties in the normalised condition, but another such steel showed the reverse effect. The quantitative influence of grain size is, however, difficult to assess, since marked structural differences often exist coincident with differences in grain size.

Estimation of Working Stresses.—The satisfactory design of high-temperature plant involves the primary necessity that the risk of failure should be absent, but beyond this lies the necessity that deformation due to stress must be restricted. Several years ago, the author compared the behaviour of several materials at various temperatures in terms of the limiting creep stress, which he defined as the stress giving a creep rate of 10^{-5} in. per inch per day at 40 days (approximately 4×10^{-7} in. per inch per hour at 1,000 hours).* This stress avoids risk of failure at working temperatures, but is too high as a working stress in view of the deformation which it produces. The fall in the limiting creep stress with temperature was considered to indicate the manner in which working stresses should be reduced as the

* ENGINEERING, vol. 135, page 533 (1933).

† Paper read before the North-East Coast Institution of Engineers and Shipbuilders, at Newcastle-upon-Tyne, on Thursday, February 22, 1940. Abridged.

* *Creep of Metals*, Oxford University Press, 1931.

service temperature was increased, and a value about one-third of the limiting creep stress was proposed as indicating the order of working stress to be used.

In recent years more precise information regarding the probable amount of deformation during service life in relation to the permissible deformation has led to the making of creep tests aiming at the determination of the stresses corresponding to deformations of 0·1 per cent. to 1 per cent. in 10,000 hours and 100,000 hours. In practically all cases published, values of these stresses are estimates; seldom have creep tests been run for more than two or three thousand hours, and none, as might be expected, for 100,000 hours. As a rule, a value of 0·1 per cent. has been chosen as a reasonable permissible deformation during service life. Some published data have been based on the admitted assumptions that the second stage in creep is reached within 1,000 hours, and that the creep rate in the second stage may be considered to remain constant during a service life of 10,000 hours or 100,000 hours. These data are expressed as stresses for 0·1 per cent. creep in 1,000, 10,000 or 100,000 hours, but the assumptions are invalid; actually the stresses are those corresponding only to the test conditions, that is, to creep rates ranging between 10^{-6} and 10^{-4} at 1,000 hours. A more rational method of estimating the required stresses consists in determining, from a series of creep tests at different stresses, the actual times for the creep deformation to reach 0·1 per cent., plotting the log. of these times against the log. of the stresses and extrapolating the curve so obtained to a period of 100,000 hours. As an illustration, the curves of Fig. 7, on page 287, have been drawn from data derived from tests on a hardened and tempered nickel-chromium-molybdenum steel. (0·31 per cent. C; 2·96 per cent Ni; 1·11 per cent. Cr; 0·49 per cent. Mo, tested at 450 deg. C. Strong evidence is afforded by Fig. 7 that the relations between log. stress and log. time for specific amounts of creep up to 0·1 per cent. are linear for this steel at 450 deg. C. A linear extrapolation to 10,000 hours and 100,000 hours appears rational, and the estimated stresses for 0·06 per cent. and 0·1 per cent. creep in these times are given in the diagram Fig. 7. A similar method of estimation was employed by Bailey* for a carbon and a molybdenum steel from creep tests made at a series of different temperatures, a fixed value of stress being used. In this case the results were plotted to provide curves relating the temperature with the log. time for specific creep which were extrapolated to 100,000 hours to obtain estimates of the temperatures corresponding to 0·1 per cent. creep.

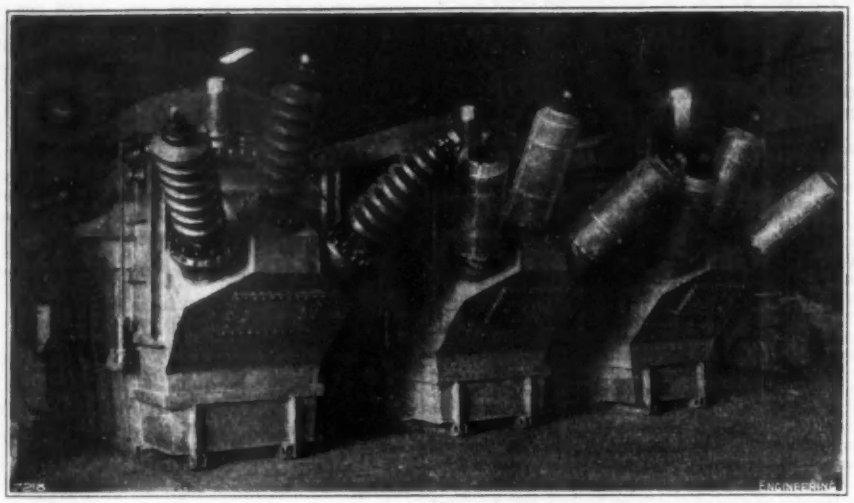
The wide variation in the creep properties of carbon steels of similar composition already described probably accounts for the marked divergencies in published values of stresses for specific creep rates or for creep deformations in a specified time. For this reason, it is felt that the best way to deal with the data is to plot curves showing the general trend in the fall of working stress with temperature and not to tabulate the stresses quoted by various investigators. Thus, Fig. 8, on page 287, in which is shown the decrease of the stress corresponding to 0·1 per cent. creep, in specific times, for temperatures exceeding 750 deg. F., depicts two such curves for carbon steel corresponding to 0·1 per cent. creep in 1,000 hours and 10,000 hours, respectively. The third curve shown is derived from Bailey's results for the stress corresponding to 0·1 per cent. creep in 100,000 hours for 0·4 per cent. carbon forged steel. This curve refers, of course, to a single sample of steel, while the former curves are applicable to carbon steels of about 0·15 per cent. to 0·5 per cent. carbon content. The author has examined carbon steels of superior and inferior creep properties to that of the 0·4 per cent. carbon steel used by Bailey, and it is probable that the trend of the plotted curve for this steel is representative of carbon steels in general. Unfortunately, the author's related numerical data are not yet available for publication. One advantage of plotting curves in the manner shown in Fig. 8 is that, although referring to 0·1 per cent. creep, they are reasonably applicable for 0·2 per cent. and possibly 0·3 per cent. creep in the times stated. Thus, from a knowledge of working stresses suitable for any temperature, say, 750 deg. F. or 800 deg. F., it is possible to calculate suitable stresses for higher temperatures. It avoids making categorical statements about suitable values of working stresses regardless of any knowledge of the actual quality of a steel which may be put into service.

Published data are insufficient for estimating working stresses for molybdenum steel on the lines described above for carbon steel. Bailey's values for the stresses at different temperatures estimated to produce 0·1 per cent. creep in 100,000 hours for a hardened and tempered molybdenum steel containing 0·29 per cent. carbon, 0·46 per cent. molybdenum, are given in Table VII.

* "The Utilisation of Creep Test Data in Engineering Design, *Proc. I. Mech. E.*, vol. 131, page 131 (1935); and ENGINEERING, vol. 140, pages 595 and 647 (1935).

STAND-BY TRANSFORMERS FOR THE C.E.B.

THE BRITISH ELECTRIC TRANSFORMER COMPANY, LIMITED, HAYES, MIDDLESEX.



Unfortunately, no other creep data were given by Bailey to show whether or not the steel was representative of its type, and Table VII refers specifically to a hardened and tempered condition of the steel. From tests carried out by the author, it would appear that other samples of the steel would show up better between 504 deg. C. and 529 deg. C. (about 940 deg. F. to 985 deg. F.). Cast molybdenum steel, approximately 0·3 per cent. carbon, and 0·5 per cent. molybdenum,

TABLE VII.—*Stresses and Temperatures for 0·1 per cent. Creep in 10^5 Hours for Hardened and Tempered Molybdenum Steel.*

Temperature, deg. C.	449	466	490	504	529
Stress, tons per sq. in.	16	10	6	2	1

appears to be of equal strength to the wrought steels above 500 deg. C., but considerably weaker at 400 deg. C. (750 deg. F.).

Examination of fractured creep specimens of several molybdenum steels has shown that intercrystalline cracks have developed during the course of the tests, have opened out, and have finally led to fracture. These intercrystalline cracks develop irrespective of the condition of the steel, for example, in the condition as rolled, normalised, hardened and tempered, etc. In addition, a considerable decrease in total creep at fracture (down to about 4 per cent.) is encountered as the time taken to fracture increases, to be followed at longer times by an increase in total creep. It was thought necessary to investigate this behaviour fairly thoroughly, and it is concluded that intercrystalline failure will not occur until at least 1 per cent. deformation has taken place. Providing, therefore, that the permissible deformation on which the working stress is to be based is of the order 0·1 per cent. to 0·3 per cent., there should be no risk of intercrystalline cracks developing during service. Molybdenum-vanadium steel has the same characteristics.

CALENDAR.—Messrs. The International Construction Company, Limited, 56, Kingsway, London, W.C.2, have sent us their monthly tear-off calendar, which, as in previous years, is fitted with a movable date indicator.

CONTROL OF IRON AND STEEL SCRAP.—The Ministry of Supply has made an Order, entitled the Iron and Steel No. 7 (Scrap) Order, 1940, which came into operation as from March 5, thus superseding the Control of Iron and Steel No. 5 (Scrap) Order, 1939. The effect of the new Order is to increase the main range of maximum prices of iron and steel scrap by from 5*s.* to 10*s.* per ton. Adjustments, to meet the changing conditions, have led to larger increases in a few cases. In substance, the scope of the Order remains unchanged, but there have been certain additions to the specifications of the material covered by the maximum-price provisions. The Direction (No. 1) under the Order, and issued therewith, repeats the provisions of the similar Direction under the previous Order exempting the sale and purchase of scrap from the requirements of licence except for certain special types. Copies of the Order may be obtained from H.M. Stationery Office, York House, Kingsway, London, W.C.2.

STAND-BY TRANSFORMERS FOR THE CENTRAL ELECTRICITY BOARD.

THE group of transformers shown in the accompanying illustration are three of five which have recently been constructed by Messrs. The British Electric Transformer Company, Limited, Hayes, Middlesex, for the Central Electricity Board. Each unit has a capacity of 30,000 kVA, and is designed for connection to a three-phase 50-cycle circuit. The primary side is wound for a pressure of 132 kV, and the secondary for 33 kV, the connections on the two sides being in star and delta, respectively. The design complies in all respects with British Standard Specification No. 171 of 1936. All five transformers are of the five-limb core type. On the high-voltage windings, tappings are provided for $\pm 2{\cdot}86$ per cent. and $\pm 7{\cdot}15$ per cent. variation, and they are connected to a five-position off-circuit linear type tapping switch, which can be operated from ground level.

Two air-blast coolers, which are equipped with forced oil circulation and are bolted directly to one end of the main tank, are provided. Each of the transformers is fitted with an explosion vent and silica-gel breather, while, in addition, dial-type thermometers and window-pattern oil gauges are standard. As will be seen, the bushings on both the high- and low-voltage sides are of the condenser type, and are protected by removable expanded-metal screens. Auxiliary three-phase transformers are mounted in small tanks above each main tank cover. These are permanently connected to the low-tension side of the main transformer, and are rated at 30 kVA. Their windings are also connected in delta and star, respectively, and they have a no-load ratio of 33,000/400 volts. No tappings are provided, but the tank is fitted with a conservator, explosion vent and silica-gel breather.

ARC-WELDING COMPETITION.

IN view of the success which attended the arc-welding competition which was conducted by The James F. Lincoln Arc Welding Foundation in the years 1937-38, this organisation has instituted a further competition to cover the period extending from January 1, 1940, to June 1, 1942. The competition will be conducted by means of papers which have to be submitted so as to reach the Lincoln Foundation not later than midnight on July 1, 1942. They will be examined by a jury consisting of representatives from various branches of engineering education and practice, as well as from the industrial field, and under the chairmanship of Dr. E. E. Dreese, Head of the Department of Electrical Engineering of Ohio State University. A detailed schedule, covering the various headings under which the papers must be submitted, has been prepared. There are twelve main classifications, subdivided into 46 sub-sections. As a result of the competition, 458 separate awards will be made, of a total value of 200,000 dols. In the sub-sections, which are termed divisions, there will be a total of 184 awards, there being prizes of 700 dols., 500 dols., 250 dols. and 150 dols. Under the main classifications, there will be a total of 48 awards of 3,000 dols., 2,000 dols., 1,000 dols., and 800 dols. There will also be

three main awards, for the best papers in any class, of 10,000 dols., 7,500 dols., and 5,000 dols., respectively, and 223 additional awards of 100 dols. each, for papers which receive honourable mention, but do not receive any of the group awards.

The main classifications cover such subjects as aircraft; containers; industrial machinery; and so on. As already stated, each of these is divided in subsections, those relating to containers being contents stationary (tanks, etc.) and contents moving (pipe lines, etc.). Complete details of the whole programme are given in a 48-page brochure which has been prepared by the Lincoln Arc Welding Foundation. The instructions in this publication are given with great clarity and there should be no difficulty in, say, any foreman, who might desire to submit a paper, understanding exactly what is required. The papers must deal with progress made between January 1, 1940, and June 1, 1942, in the re-design, manufacture or construction of an existing machine or structure by the application of arc welding to a procedure which has previously been carried out in some other way; or the design and construction of a machine or structure not previously made and which illustrates how a useful result, not otherwise attainable, has been obtained by arc welding. Papers may also be submitted dealing with the organisation of a welding service, either for new work or maintenance and repair.

The author of a paper must have been actually engaged on the subject-matter with which it deals. It must have been carried out by the firm with which he is connected, but those who are not employees of the firm, but have been concerned in the design or manufacture, may submit a paper. More than one paper may be sent in from one firm, provided they deal with different subjects, and papers may be signed by one or more authors. The relation of the author, or authors, to the firm should be stated. The papers should be written in practical language, readily understandable by those concerned with welding. Copies of the instructional brochure may be obtained from The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio, U.S.A. To serve the interests of intending competitors in this country, an office has been opened in London, from which any necessary information or copies of the brochure may be obtained. The address is Mr. Robert Butler, Secretary, James F. Lincoln Arc Welding Foundation, Thames House, Millbank, London, S.W.1.

As we understand that, in the 1937-38 competition, some 60 per cent. of the awards were made to entrants from the British Empire, it may be expected that the new opportunity which has been presented will be taken full advantage of from the same field.

THE APPLICATION OF ELECTRICITY IN BRITISH SHIPS.

In a review entitled "Trends in the Application of Electricity in British Ships," which appeared in the February issue of the *Journal of the Institution of Electrical Engineers*, Mr. G. O. Watson stated that, during the last three years, progress has mainly been in the direction of improvement in quality of materials and methods of installation. An exception to this statement is the important developments in Germany in the use of alternating current for Diesel-electric propulsion. This is of outstanding importance and has been successfully and extensively applied. The uses to which electricity is put continue to extend and any development in the direction of new appliances finds a ready demand in ships, particularly those catering for passengers. The provisions made for the benefit of passengers using electricity are considerably in advance of any to be found on land, either in hotels or in private houses. The principal innovation during the past three years has been the introduction of fluorescent-tube lighting in the public rooms.

After a reference to the third edition of the "Regulations for the Electrical Equipment of Ships," which was published by the Institution of Electrical Engineers in September, 1939, the review goes on to say that in British ships direct current continues to be the only system used, except where it is necessary to convert to alternating current for special purposes, such as discharge-tube lighting and gyro-compasses. For several years no British ship has been equipped with alternating-current distribution or with a higher direct-current voltage than 220. As cables and their installation constitute on the whole the largest single item in the cost of equipment and maintenance, it is not unnatural that they continue to receive considerable attention, and it is satisfactory to note a steady improvement in quality both as to the cables themselves and in the method of installation. The quality of rubber has undoubtedly improved as a result of better methods of sampling and testing, improved technique in mixing and composition, and better control during manufacture and vulcanisation, resulting in a more uniform and reliable product. The use of pure rubber next to the conductor has at last been abandoned. Research has also shown the advantage of lead alloys in resisting cracking due to vibration, and the composition of these alloys is now standardised.

A sheathing known in the trade, for want of better nomenclature, as "HR-type," gains ground as a result of roughly 10 years' experience. It is a rubber composition which behaves well in the presence of Diesel oil and, while preserving the dielectric from influences of this nature, is not subject to cracking. A new fireproof cable with a highly compressed refractory mineral insulating material, copper-sheathed, has made its appearance and has been tried out on a relatively small scale, and during the short period it has been in service it has proved successful. Sealing the ends of all types of cable, including those insulated with rubber, has proved beneficial and will undoubtedly be adopted more extensively in the future. Experience has shown that the majority of cable failures occur within 6 ft. of the ends owing to moisture creeping up the strands and also from too high a temperature at the terminals. The latter is being taken care of by stricter attention to the temperature of switch and, more particularly, of fuse terminals. No radical change has taken place in the method of installing cables, but there has been a distinct improvement in the method of clipping and fixing, and more care and supervision is given to the pre-selection of suitable locations free from heat and oil. The fixing of cable clips to steel bulkheads, requiring some thousands of studs, has led to the development of an interesting welding equipment to replace drilling and tapping. The studs are of naval brass, $\frac{1}{4}$ in. and $\frac{5}{16}$ in. diameter, and they are welded to the steel plate. The duration of the arc is about 0·25 second with $\frac{1}{4}$-in. studs, and slightly longer with $\frac{5}{16}$ in., and the current is approximately 230 amperes direct current.

More extensive use is being made of telephones and a development of considerable importance, since it is independent of any source of electrical supply in an emergency, is that of sound-powered telephones. The necessary electrical energy required for the transmission of speech from one station to another is actually generated by the voice of the operator. Calling is provided by means of a generator of special design driven by ratchet and lever, to make a call it being only necessary to pull a lever through 90 deg., producing a loud ring for approximately $1\frac{1}{2}$ seconds at the distant station. A special feature due to the fact that there is no background noise is that quality of speech is of a very high degree of intelligibility and immune from interruption caused by local noises. This dinproof property is of great importance in connection with instruments housed in noisy situations such as engine rooms. Tests have shown that it is possible to transmit and receive messages distinctly with a noise level of 120 phons, which is generally considered to be about the limit of human endurance.

Growth in the number of radio services has brought with it many ancillary problems, particularly that of the suppression of man-made interference, which is accentuated by the low field strength of signals. These services include direction-finding, telegraphy, radiotelephony and broadcast reception. Also allied to this problem is that of diffusion of broadcast programmes throughout the ship on loud-speakers. A better appreciation of these services and the problems involved will be obtained by considering briefly the equipment of a large passenger vessel, such as the new Mauretania, which is equipped with long-wave, medium-wave, and short-wave transmitters, combined with a system of frequency selection which enables any one of 18 short-wave frequencies, eight medium-wave frequencies, and eight long-wave frequencies, to be employed with a delay not exceeding 10 seconds to 15 seconds. Highly-selective receivers permit the simultaneous use of three telegraphic channels, news and weather reception, as well as broadcast bulletins, while the direction-finding and auto-alarm services are independent of the normal communication channels. The ship-to-shore or inter-ship telephone service is carried out on a special transmitter. There are also emergency and life-boat installations, and a public-address system. At the opposite extreme of size, marked advances have been made in the low-power telephone transmitters for use in small vessels which are not compulsorily equipped with wireless apparatus, such as trawlers. These instruments are usually arranged so that they can transmit only on certain predetermined frequencies, which are stabilised by crystals.

The replacement of spark transmitters by valve transmitters, the introduction of crystal and stabilised loose-coupled circuits, and the rigorous application of international regulations, have during the last few years led to an immensely increased efficiency in the use of marine-frequency allocations. From January 1, 1940, no spark transmitter of 300-watts alternator output or over will be permitted, so that there has been in progress a change-over in the type of transmitter in use in a very large number of ships. Valve transmitters giving I.C.W. or C.W./I.C.W. are being substituted. The use of short-wave transmitters, enabling ships to maintain daily touch with their home country, has extended very much in recent years. From being almost confined to large passenger ships, their use has spread to cargo ships and particularly to tankers. The use of radio-telephone sets, operated by members of the crew unskilled in morse, has extended very much in British coastal shipping. This has been due to the facilities given by the G.P.O. at their coast stations, Humber and Seaforth radio now being available through Portpatrick. The latter gives facilities superior to the others at present, in that it provides facilities for duplex communication instead of simplex conversations, such as are available through the other stations mentioned. Stabilised frequency of emission has promoted the use of highly selective receivers having stabilised frequencies of reception and made possible automatic services, which previously had demanded skilled operation. The introduction of the "link telephone service" by the G.P.O. has increased enormously the value of the 2-megacycles per second telephone band in marine mobile services, and the use of true duplex services between ships in this band is steadily expanding. Investigation of aerials and aerial constants is proceeding, and it is becoming normal to use a single aerial for transmission or reception on all wavelengths.

The latest developments in wireless apparatus are generally directed towards improved frequency stability, improved efficiency, and reduced costs. In these directions the introduction and use of crystals having low-temperature coefficients has largely removed the need for thermostatically-controlled heat chambers, while at the same time the development of stabilised loose-coupled circuits in both scientific and commercial establishments will in the future enable the advantages of high stability together with accurate frequency selection to be applied to marine communications. The efficiency of the average marine transmitter is of a high order, but the eternal questions of size, weight and power consumption are invariably under review by the engineers responsible for these matters. The more modern low-temperature low-voltage valves are being adopted, and all new developments in materials and processes, both electrical and mechanical, have become part of the development engineer's stock-in-trade.

The research problems claiming immediate attention are largely concerned with the minute investigations of innumerable problems which, though in themselves not of a major order, may ultimately produce a matter of first-rate importance. The most serious of these is still the question of a stabilised frequency control which permits of the most minute and accurate adjustment. Another is the difficulty of obtaining any precise frequency adjustment from a loose-coupled oscillator immediately upon switching on. Further problems are concerned with the commercial application of scientific discoveries, *e.g.*, visual direction-finding, remote frequency control, penetration of fog by the reflection of electromagnetic rays, applications of television, and variable-frequency modulation.

Electricity plays an ever-increasing part in aiding the navigator, reducing and eliminating risks. Progress in depth-sounding has steadily advanced, both in the number of equipments and performance. The method of indication of depth is in some cases visual; in others, a permanent or semi-permanent record is obtained. There are two chief methods of obtaining soundings by echo from the sea bottom—the piezo-electric and the magneto-striction. The piezo-electric installations are usually fitted in trawlers, accompanied by visual indicators. As a rule, ocean-going ships are equipped with recorders, almost always electrolytic. In many cases a visual indicator is fitted as well as a recorder. The magneto-striction equipments, being much more easily adapted to the use of high power, are usually installed so as to operate through the skin of the ship, thus avoiding piercing the hull and making it possible to fit the equipment while the ship is afloat. For this reason, they are popular in big ships.

Development and research have been in the main directed to overcoming the two chief difficulties which beset to some extent all types of echo-sounding devices. In the first place, there is always a difficulty in measuring very shallow depths of water under a ship. The second difficulty is due to the comparative capacity of disturbed water to supersonic pressure waves, making it difficult to obtain satisfactory operation in ships which are very light in the water, especially in fast ships trimmed very light forward. There are, however, certain positions under the bottom of a ship which are comparatively clear of trouble of this nature, and projectors can now be so placed as to ensure good working under almost any conditions of draught, speed and trim. Owners of fishing vessels find a dual advantage in the possession of depth-sounding apparatus, as it will indicate also the presence of shoals of fish.

(*To be continued*).

LABOUR NOTES.

A DEPUTATION from the Trades Union Congress again discussed with the Prime Minister last week their plea, originally submitted a year ago, that the provisions of the Trade Disputes and Trade Unions Act, 1927, should be amended in certain important respects. The T.U.C. desires, it is understood, that the position should be restored to that existing before the Act was passed, which would mean that Civil Service unions would once more be free to associate with the general Trade Union Movement, that the restrictions which the Act imposed on picketing during disputes would be removed, and that unions would be entitled, as before, to collect the political levy from members who did not "contract out" instead of obliging them to "contract in." Mr. Chamberlain said, in the course of his reply to the deputation that, since he last saw the representatives of Congress on the subject the position had been completely changed by the outbreak of war. Any alteration of the provisions of the Act would require legislation. He felt that, apart from the merits of the case, it would be impracticable to introduce, in war-time, such legislation which would, of necessity, be highly controversial. He trusted, therefore, that, with the object of concentrating attention upon the supreme task of winning the war, the Trade Union Movement would not press for reconsideration of any of the provisions of the Act at present. He was well aware and appreciative of the support which the Trade Union Movement was giving to the national war effort. He felt that its record in that respect would proportionately strengthen its position in any representations that it might desire to make at the conclusion of the war.

It was mentioned in these notes a week ago that a claim for a 10 per cent. increase of wages to electrical workers employed by the main-line railway companies had been submitted to the Industrial Court by the Electrical Trades Union, the National Union of Railwaymen and the Amalgamated Engineering Union. The Court has found against the claim; but it recommends that the National Railway Electrical Council should adjust the rates of wages of switchboard and sub-station attendants and assistant switchboard and sub-station attendants.

At a meeting last week, attended by 1,000 London members of the Electrical Trades Union, a resolution was adopted declaring that any attempt to introduce dilution in any form would be resisted, and calling upon the executive council unconditionally to oppose encroachments. "We fail to see," the resolution continued, "why the introduction of dilution has ever been suggested while there is a surplus of skilled labour in London available for work in the provinces, providing the employers are prepared to pay the appropriate rates of wages and a subsistence allowance of 2*l.* a week, and the age in the schedule of reserved occupations for electricians is reduced in order to conserve a sufficiency of skilled labour for the industry."

Although the weather had, in general, improved by February 12, when the count of the unemployed was taken, the effect of long-continued frost and snow in causing temporary unemployment was still more marked at that date than when the previous count was taken in January. Outdoor work was still hindered in many areas and short deliveries of materials or inability to transport output had dislocated working conditions in a large number of cases. The monthly statement by the Ministry of Labour and National Service points out that there was, nevertheless, a drop of 80,145 in the number wholly unemployed and casuals between the two dates, but the number temporarily stopped increased by 65,349, leaving a net reduction of 14,796. During the fortnight following February 12 the continuance of better weather enabled much of the dislocation to be remedied, and there was a large drop, estimated at about 200,000, in the numbers registered.

Unemployment decreased between January 15 and February 12 in tailoring and dressmaking, hotel and boarding-house service, the distributive trades, local government service, printing and bookbinding, motor-vehicle, cycle and aircraft manufacture, and laundry service. On the other hand, there were increases in the numbers temporarily suspended from work in agriculture, horticulture, etc., coalmining, building and public-works contracting, iron and steel and tin-plate manufacture, the brick and tile industry, stone quarrying, shipbuilding and repairing, and textile bleaching, dyeing, etc. Unemployment was lower by 392,618 than on February 13, 1939.

Between January 15 and February 12, the numbers of unemployed persons on the registers decreased by 26,859 in the London area, 3,817 in the Southern area, 7,558 in the South-Western area, 12,776 in the North-Western area, and 764 in Scotland. They increased by 6,879 in the Eastern area, 8,751 in the Midlands, 8,181 in the North Midlands, 961 in the North-Eastern area, 7,430 in the Northern area, and 4,776 in Wales.

In February, the home-branch membership of the Amalgamated Engineering Union increased from 378,397 to 385,465, and the colonial-branch membership from 36,929 to 36,933. The number of members in receipt of sick benefit increased from 7,825 to 11,807 and the number of superannuated members decreased from 13,972 to 13,899. The number of members in receipt of donation benefit decreased from 750 to 708, and the total number of unemployed members from 3,427 to 3,225.

The writer of the editorial notes in the March issue of the *Journal* of the Amalgamated Engineering Union states that the summarised financial transactions during the second half of 1939 show, "as was anticipated, a substantial increase in the funds" of the organisation. "We commenced the half-year," he says, "showing a total value of 2,943,255*l.* At its termination that had increased to 3,183,673*l.*—an addition for the period of 240,418*l.* The payments for superannuation benefit have increased by 1,800*l.*, while the amounts disbursed in sickness and donation benefits are reduced by 13,399*l.* and 9,550*l.*, respectively. This result," the writer goes on to say, "has been achieved by the cordial co-operation of branch secretaries and other officers, and if we are to weather the storm that will be inevitable when munition requirements diminish, our present policy of wise spending must continue."

In the course of a note dealing with the subject of man-power, the editor says: "We are satisfied that the personnel must be augmented in order to carry out the Government's war programme, and that such augmentation will have to be met from persons not previously connected with the industry; in this connection, it is the first duty of the State to ensure that every unemployed male worker is employed before embarking upon a policy of introducing extraneous people, many of whom may not previously have been associated with industry, in a manual sense."

Judging from accounts which reach us from some ship repair centres, one way of appreciably increasing the available supply of skilled labour is being neglected. There is local insistence here and there that engine-room complements must not do machinery repairs in their own ships, but that most of the work must be carried out by shore fitters. Obviously, if there were no local embargoes of that character, more skilled men would be available for other pressing jobs.

Submitting the toast of "The Society" at a luncheon of the Women's Engineering Society, last week, Mr. Ernest Brown, Minister of Labour and National Service, said that in the last two decades there had been a growing acceptance of women's place in industry, trade, and commerce. Women of the Engineering Society could have no doubt as to the value of their work at the present time, and there was an immense field for women represented by the war effort. A matter of vital concern at the moment was the expansion of the engineering industry, and discussions were proceeding with both sides on matters of labour and national service. While no attempt could be made to anticipate the outcome, he was grateful for the manner in which both sides were responding to the need in the national interest to get to grips at once with the problem of expansion. The atmosphere could not be better. Unfortunately, the impact of war had seriously affected a number of industries where women predominated. But the Government programme was immense, and it was confidently expected that every person who was suitable and available for employment would be required in numbers far in excess of those counted as unemployed.

Under an agreement negotiated by the Amalgamated Engineering Union with the Flour Milling Employers' Federation, wage increases ranging up to 9*s.* and 10*s.* a week have been secured for mechanics in the flour milling industry. The new rates, which are to operate as from February 1, are 79*s.*, 77*s.* and 75*s.* a week, according to class. Overtime rates are time and a third for the first two hours and time and a half afterwards. Working hours are reduced from 47 to 44 a week, and for the first time, there are to be 12 days paid holiday a year at all mills.

Lecturing at the City of Birmingham Commercial College on the subject of "The Factory Manager and the War," Mr. A. Healey, works director of Messrs. The Dunlop Rubber Company, said that the urgent demand for men for semi-skilled operations had necessitated new ideas on labour training methods. The old method of putting the new recruit by the side of a trained workman to learn a job was impracticable. Special intensive training was found to reduce the normal time from six months to from three to four months. The labour situation had been somewhat relieved by the suspension of some parts of the Factory Act, and the modification of other parts. Although the factory inspectors had been most helpful, it was not considered good policy on the part of employers to take full advantage of these concessions. Long hours were bad from the points of view of both employers and operatives.

Industrial and Labour Information states that the United States Maritime Service, set up by the Maritime Commission under the Merchant Marine Act of 1936 to train United States seamen, has taken measures to give assistance to seamen becoming unemployed in consequence of the Neutrality Act. The Maritime Service proposes to enrol 8,360 seamen every year (960 officers and 7,400 ratings) in training stations already controlled by it or to be established. During the emergency period enrolment will be open only to those whose vessels have been laid up in consequence of the Neutrality Act. For this reason, the Merchant Service has made it a condition of enrolment that the applicant must produce a certificate of discharge showing that he was a member of the crew on the last voyage of a vessel withdrawn from service by operation of the Neutrality Act; he must also show one year's active service at sea within the last three years.

The training programme, which lasts for three months, will consist of special training for officers, training for deck and engine-room ratings, and practical courses for members of the stewards' department. While engaged in this training, the officers will receive 125 dols. a month and seamen 36 dols. a month, plus allowance for food (18 dols. a month), laundry (1 dol. a month), clothing (55 dols. for three months), and transportation (10 dols. for three months). In addition, medical and dental services will be given free. The Maritime Service has also undertaken the organisation of spare-time activities for the seamen undergoing training.

New regulations affecting workers in State transport undertakings in Yugoslavia have been laid down by the Minister of Communications. They apply to workers employed in State transport undertakings by land and sea (except river transport), industrial manual workers and apprentices. These are divided into: (1) Regular workers who may become permanent under the conditions laid down in the regulations, one of which is three years' service. (2) Apprentices. (3) Workers engaged under a contract. The remuneration consists of a basic wage varying according to the workers' qualifications and length of service, and a supplement based on the cost of living in the place of employment, the working system in the undertaking concerned, the workers' skill and any special conditions in the task or trade in which the worker is engaged.

Overtime and work on holidays, except shift work on continuous processes, is paid for at time and a half; journeys to and from work are not considered as overtime, although paid for according to the regulations. Wherever the nature of the work permits, and especially in the workshops and locomotive depots, piecework or a system of bonuses for time saved and increased output is to be introduced. For this purpose, there will be drawn up a series of tables of hours of work permitted, described as chronometric tables, and a table of wages for piecework. Bonuses for time saved will be paid according to rules laid down in the regulations. For those whose work calls for specially exhausting physical activity, normal hours of work are eight in the day. There is no work on holidays and Sundays, except in urgent and exceptional cases. Hours of work may be reduced if the needs of the service so require, subject to restrictions in regard to permanent workers. For work carried out under specially difficult conditions, hours may be reduced to six in the day without reduction of wages. Overtime is only permitted in cases of urgent necessity. Workers are prohibited from taking part in any action intended to bring about a slackening or cessation of work.

SUBSTATION FOR MESSRS. FIELDING AND PLATT.

MESSRS. BRUSH ELECTRICAL ENGINEERING COMPANY, LIMITED, LOUGHBOROUGH.

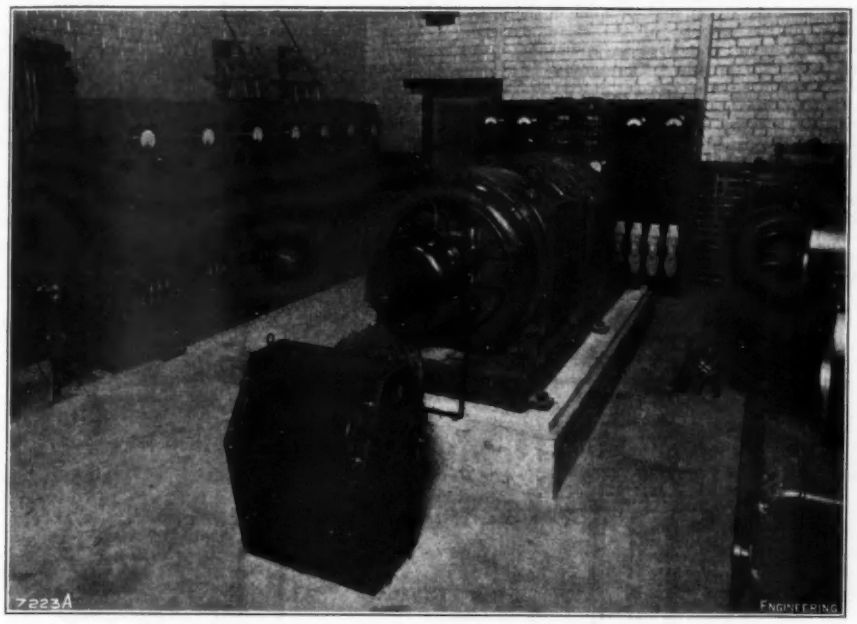


FIG. 1.

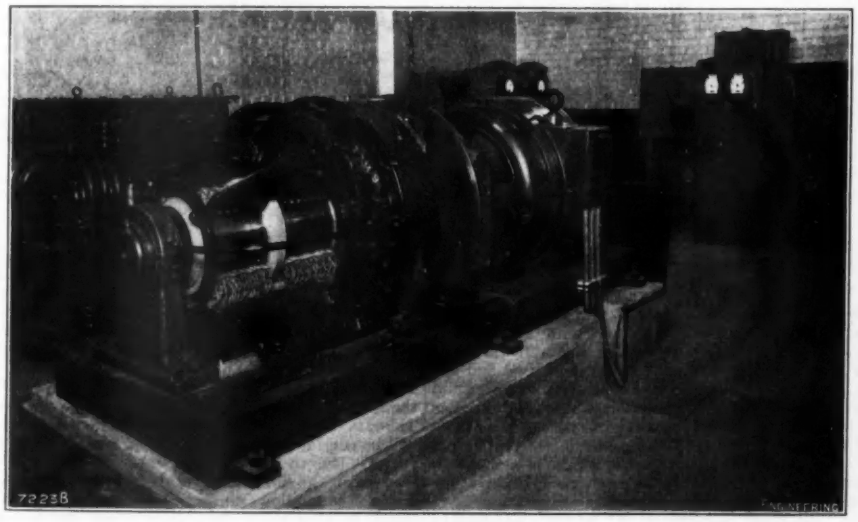


FIG. 2.

700-KVA SUBSTATION AT THE WORKS OF MESSRS. FIELDING AND PLATT, LIMITED.

UNTIL recently, the engineering works of Messrs. Fielding and Platt, Limited, Gloucester, were supplied with power from a reciprocating engine driving a direct-current generator, a secondary low-tension alternating-current supply being taken from the Gloucester Corporation's mains. An extension of the premises, due to an increased demand for hydraulic presses and oil engines, and the consequent installation of new multiple-unit machine tools with individual drive, and large testing machines, necessitated an alteration in these arrangements, and it was decided to take a further high-tension current supply from the Corporation through a works substation. The equipment for this station has been supplied by Messrs. The Brush Electrical Engineering Company, Limited, Loughborough, and comprises the bulk-supply ring-main switchgear, additional high-tension and low-tension control boards, transformers, a motor generator with liquid starter, and the necessary direct-current switchgear. A general view of the interior of the substation appears in Fig. 1.

The new high-tension switchgear is of the Brush Company's vertical-isolation metal-clad air-circulated type and comprises oil circuit-breakers with a rupturing capacity of 150,000 kVA. The ring-main isolating switches are of the oil-break extensible type, to facilitate possible future extensions. Two transformers are installed, each of which has a capacity of 350 kVA. These are of the oil-immersed natural self-cooled pattern, and step the pressure down from 10,500 volts to 400 volts. Tappings are provided on the high-tension side for $\pm 2\frac{1}{2}$ per cent. and ± 5 per cent. variation in the incoming voltage. The tanks are of the boiler-plate tubular type, and are mounted on rollers. The design is generally in accordance with the appropriate British Standard Specification, and the windings are connected in star with the neutral point brought out on the low-tension side. The motor-generator set, a view of which appears in Fig. 2, was, of course, installed to provide a suitable supply to the existing direct-current plant. It consists of a 300-h.p. 400-volt slip-ring induction motor, which is directly coupled to a 200-kW 110-volt generator. This generator is of the protected type and is provided with a pedestal roller bearing at the commutator end and an end-shield bearing at the fan end. The construction is of the Brush standard type, but special attention may be drawn to the tandem brush holders, which are staggered to ensure good commutation under all conditions of load and to maintain even commutator wear. Mechanical rigidity of the long commutator is obtained by a shrunk ring, which is fitted centrally. The motor is of the screen-protected type, and is controlled from the 400-volt alternating-current switchboard by a liquid rotor starter.

The medium-tension alternating-current switchgear is of the stationary sheet-steel cubicle type, and incorporates oil circuit-breakers and gang-operated isolating switches. This switchboard was constructed by the Brush Company and beside it is an iron-clad distribution board manufactured by Messrs. J. H. Holmes and Company, Limited, Hebburn-on-Tyne. Finally, the Brush Company installed a direct-current switchboard, which controls the output from the motor generator and two outgoing feeders. The whole of the interconnecting cables were installed by the West Gloucestershire Power Company.

THE CIRCULATION OF WATER AND STEAM IN WATER-TUBE BOILERS, AND THE RATIONAL SIMPLIFICATION OF BOILER DESIGN.*

By W. YORATH LEWIS and STRUAN A. ROBERTSON, B.Sc. (Eng.).

IN the design of water-tube boilers, a knowledge of the mechanics of circulation is indispensable if the arrangement of the tubes and the fixing of their dimensions is to be carried out satisfactorily. Even to-day, in spite of many attempts by investigators in all countries, the mechanics of water and steam circulation is a subject not fully understood. In the past, boilers have operated apparently in a satisfactory manner in spite of these errors. To-day, however, with increasing pressures and capacities, there can be little doubt that these faulty theories are having a very pernicious effect. Without correct knowledge the design of the boilers is merely empirical, and bad features of former designs are carried forward uncorrected in new designs. With most types of boilers, it is impracticable to attempt any analysis of the circulation, due to the indeterminate divisions of the flow between tubes connected in parallel between drums and headers. Some simple type of boiler, in which the flow can be calculated accurately, requires to be established as a standard of excellence. Using this standard, the performance of more complicated designs can be estimated, the effect of deviations from the standard studied, and guidance obtained in designing a boiler which is as near the standard as possible.

The standard proposed by the authors consists of the U-tube boiler in Fig. 1, on page 292, having a single water and steam drum, with a single U-tube, the right-hand leg of which is the upcomer, and discharges its contents above the level of the water in the drum. The tube is considered to be capable of being heated to any required intensity, and over any required sections of its length. The actual method of obtaining this heat is immaterial, since the standard is concerned with circulation only. The dimensions are shown in Fig. 1, but, while quite arbitrary, thould not affect the theory of circulation. Possibly, with other dimensions, a standard tube could be designed to give adequate circulation under a wider range of pressures and rates of heating than the tube selected here.

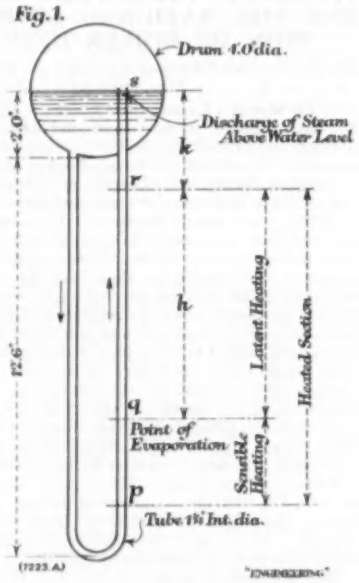
The Change from Water to Steam.—The change from water to steam is not a simple one. A certain amount of research has been undertaken on it in recent years, particularly in America and Germany. Most of the investigators have been concerned chiefly with evaporation at or below atmospheric pressure, in steam-heated evaporators. Not a great deal has been done at the pressures and rates of heating usually required in water-tube boilers. Experiments have been made by the authors, using the apparatus shown in Fig. 2, page 292. The upper drum has glass sides. Two of the glass tubes, A and C, have within them a steel pipe $\frac{3}{8}$ in. diameter, through which saturated steam may be passed at pressures up to 120 lb. per square inch. The temperature difference between the steam in the inner tube and the water in the annulus is sufficient to cause violent ebullition, simulating the action in a tube of a water-tube boiler. The pressure of the steam enables the temperature to be known, provided there is always a discharge of steam to waste. This gives a rough indication of the heat-transfer rate, which varies with the velocity of the steam and of the contents of the annulus. The central tube B, which is unheated, may act as a downcomer, or it may be stopped up, in which case the two remaining tubes form a U-tube boiler similar in general principles to the standard U-tube. The evaporation from water to steam in a vertical tube, in which the contents are flowing upwards, takes place as a result of two causes, first, the heat absorbed from the tube wall, and second, the reduction in pressure as the liquid rises in the tube.

* Paper read before the Institution of Mechanical Engineers, on Friday, March 1. Abridged.

The general mechanism of boiling in a tube is illustrated in Fig. 3, herewith, which has been prepared by the authors to illustrate the findings of other investigators, together with results of their own experiments. Up to section A there is water only in the tube. At the velocities usual in water-tube boilers, the flow will be turbulent. On any cross-section there is a thin boundary layer, next the tube wall, moving with laminar or viscous flow, then a transition zone, then the turbulent core. The temperature drop, between the inner tube surface and the water core, is concentrated almost entirely in the boundary layer, across which heat moves mainly by conduction. In the turbulent core, heat is quickly distributed by eddy currents, so the temperature is approximately uniform. Above A, when the temperature of the water immediately in contact with the tube is high enough, small bubbles of steam form on the tube wall.

Due to the surface tension of the water enclosing a spherical bubble of steam, the pressure in the interior of the bubble is greater than the pressure in the water.

Fig. 1.

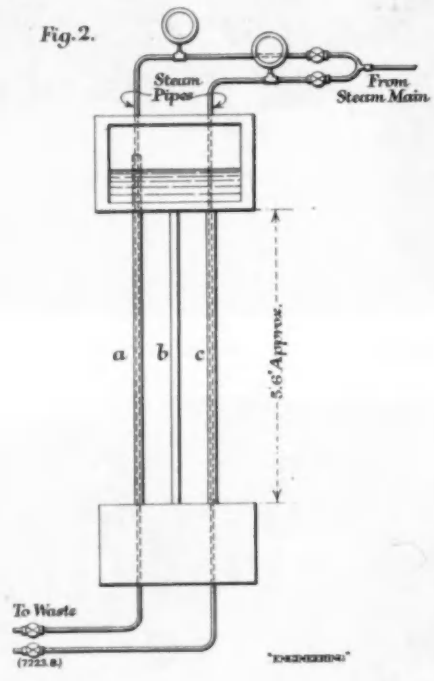


If no particles of air or other nuclei are present to start the formation of bubbles, boiling will not begin until the temperature is raised much above the point corresponding to the external pressure, that is, the liquid becomes superheated, above saturation temperature. Once formed, the bubble would be highly unstable, for, as the radius increases, the tension in the envelope becomes less and less able to balance the excess of pressure within it, and the expansion into vapour would take place with explosive violence. A bubble formed on the heating surface will grow till it is swept off by the moving liquid film, or till it bursts through the film. The bubbles, once dislodged, travel inward towards the core of the tube. At first, this core is not sufficiently hot to enable the bubbles to exist, and the bubbles collapse after a very short journey. This occurs in section A B of the tube. By condensing, and giving up their latent heat, the bubbles contribute towards raising the core temperature to saturation temperature.

Above B, the core temperature is sufficiently high to enable the bubbles to become permanent and increase in number and size. They rise, since their upward velocity is greater than the upward velocity of the water. Although, in the earlier sections of the bubble stage, the distribution of the bubbles is fairly uniform, after a point they seem to gather in clouds, as at C, separated by sections in which the bubbles are less numerous. Various observers have described how, after a certain point D, the bubbles of each cloud coalesce, to form a single large bubble, occupying the whole area of the tube. The water displaced during this action forms a slug of water above the large steam bubble, and the steam pushes this slug ahead of it. Between D and H, there is a section of "slug action," the tube being occupied by alternate slugs of water and steam, travelling with equal velocity. There is still a film of water on the tube wall between the steam and the metal. As they travel upward, the water slugs become thinner, due to continued evaporation within them, until they finally break up at K.

From H to M, there remains only a film of water on the tube wall, with occasional bulges, as at K and L, which remain from former slugs of water. This water film travels upwards, but at a speed less than the steam speed. It evaporates by the small bubbles of steam forming on the tube wall, and being either swept off by the movement of the film, or bursting through the film. During the breaking up of the slugs, and during boiling of the film of water on the tube wall, the bursting of steam bubbles into the general column of steam entrains particles of water into the core. These travel upwards with the steam, and form one of the principal elements in the wetness of the steam. Above M there is wet steam, that is, steam containing drops of water, passing up the tube. These gradually evaporate until the steam becomes dry saturated, at N. Above this point superheating begins. No experimental information is as yet available as to the actual dryness fraction of the steam represented by the different sections in Fig. 3. In the author's experiments, with the maximum rate of heating, the froth stage appeared quite short, as also did the slug stage, while the stage in which steam contained drops of water appeared to persist throughout for the remainder of the tube. The film of water on the wall of the inner tube, from which the heat was being derived, appeared to be

Fig. 2.



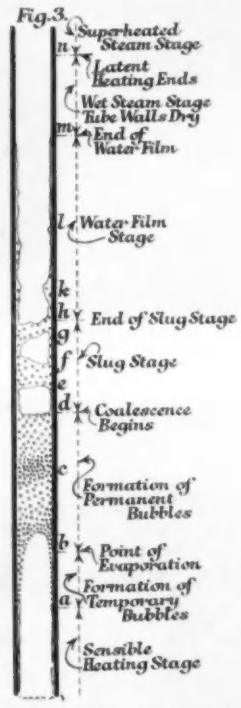
quite thin, similar to the wetness on an ordinary wet pipe. The possibility of this wet film evaporating, however, was shown in other experiments in which the flow was purposely arranged to be defective, and the film could be seen drying up. The slugs of water and steam formed during evaporation are not the same as might occur in a water-tube boiler having bad circulation and stagnation, or due to water entering the tube from the top end. If the upper part of a tube is cool, steam formed at the lower parts may condense again and flow down, interrupting the processes of evaporation.

An important consideration, arising out of the division of the evaporation into the different sections, is the effect on the heat transfer coefficients. This, in turn, affects the permissible heating rates, and also may have an influence on the permissible maximum dryness fraction of the steam issuing from the tube, if the temperature of the metal of the tube is to be kept within safe limits. There is little practical experience of established practice or experimental data on which to form a judgment. For most boilers, due to indeterminate flow, it is quite impossible to estimate the dryness of the steam issuing from any particular tube. In certain forced-circulation boilers, in which the makers claim to be able to predict the flow in any tube and the heat applied to it, a dryness fraction of 0·17, that is, a "six times round" boiler, is considered to give satisfaction. The subject merits further investigation. In this paper, a dryness fraction of 0·20 at exit will be looked on as satisfactory, though the value should really vary with pressure, as affecting the saturation temperature and hence metal temperature, and also the film thickness corresponding to any given dryness fraction. It should be noted that the metal temperatures referred to in this section are for the inside tube surface. The temperature at the outside tube surface will be greater.

In the section of the tube containing water, if the temperature drop between the tube wall and the water is very high, a blanket of steam may form next the tube wall, offering a high resistance to the flow of heat to the interior of the tube. Heat can only pass this layer by conduction. The coefficient of thermal conductivity of steam is considerably less than that of water. The phenomenon is comparable to the cushion of steam which supports a drop of water on a very hot plate, when the drop assumes the "spheroidal state." The possibility of a blanket layer of steam existing in a boiler tube, setting a maximum value to the rate of heat transfer to the contents of the tube, merits further experimental consideration. The effect of such a blanket would apply only to the tube up to section M, where the water film ceases. Whether or not it has an appreciable effect when the contents of the tube are in motion, it must have a very serious effect if there is stagnation in the tube. With stagnation, the tube temperature may rise to a very high value if the water in the tube is protected by a steam blanket. Once the water is evaporated, the steam temperatures may rise to heights approaching the flame temperature of the external gases.

The Standard U-Tube Boiler.—The flow in the U-tube boiler proposed as a standard of excellence,

Fig. 3.



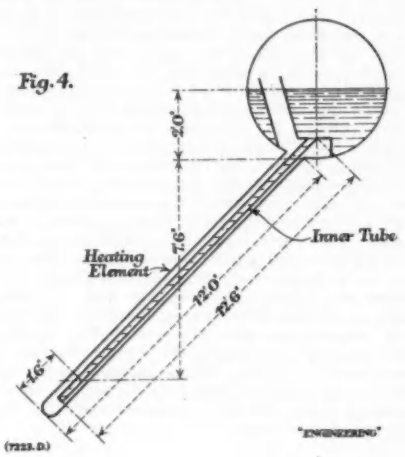
may now be examined in detail. The point at which evaporation commences corresponds to B in Fig. 3, when the steam bubbles form and are permanent. It is referred to later as the "point of evaporation," though it is the point of commencement of evaporation. The rate of heat absorption by the contents of the tube will be considered uniform over the heated length P R, Fig. 1. Due to the variation in the resistance to heat transfer in the different sections of water flow, boiling, and wet-steam flow, uniformity of heat absorption will imply varying tube temperatures, and hence various temperatures of the outer heating medium.

The maximum intensity of heating may be much more than the average. For convenience, however, calculations are based on the average heat absorption per unit area of the total outer circumferential surface of the tube. If the feed water supplied from external sources to the drum is at saturation temperature, then it is possible to say at once that the water in the downcomer tube is at saturation temperature, and the point of evaporation is at P, Fig. 1. If the external feed-water supply is at a temperature less than saturation temperature, a rather indeterminate state of affairs in the drum will exist. Where does this feed water receive the extra sensible heat which is required to bring it to boiling point? Some guidance in answering this may be derived by examining two extreme possibilities, between which the truth must lie.

On one hand it is possible that the sensible heat is derived directly from the fire, as the water passes round the U-tube. If this is the case, the water in the drum must evidently be at less than saturation temperature. The apparent anomaly of having steam in contact with water at a temperature lower than saturation temperature may be explained by the presence of layers of water in the drum at different temperatures, the water at the surface being at saturation temperature. The other extreme possibility is that all the sensible heat is obtained in the steam drum, before the water begins to circulate at all. Cold feed-water entering the drum will tend to reduce the tem-

perature of the water in the drum. This, in turn, will tend to cause condensation of some of the steam in the drum, and to lower the pressure. A state of equilibrium will be obtained when the latent heat from the condensed steam has been enough to raise the fresh feed water to saturation temperature. Thus, of the mixture of steam and water issuing from the upcomer tube into the drum, the water returns immediately to the water in the drum, some of the steam condenses, and the remainder of the steam flows out through the steam main.

The truth must be between these two. Part of the sensible heat is no doubt derived directly from the fire, and part by condensation of steam in the drum. The error in assuming Q, Fig. 1, as the point of evaporation, dividing P R in the ratio of sensible heat to latent heat will be small. The rate of heating and the rate of heat absorption in an actual boiler tube vary considerably along the length. The position of the point of evaporation can only be determined roughly by taking into account all the variable factors, and estimating their effect. Having determined the position of the point of evaporation, the head causing flow in the tube; the frictional resistance to flow; the pressure drop to produce acceleration; and the pressure variations in the tube, may be calculated.*



For any assumed rate of absorption of heat by the contents of any part of the U-tube, the head producing flow may be calculated. The requirements which this head has to fulfil are four in number. (1) It must overcome the pressure drop at entrance to the tube. (2) It must provide the water with its kinetic energy. There is, of course, no relation between this kinetic energy of the water, which must necessarily be derived from the available head, and the kinetic energy of the steam, which, as already explained, is derived mainly from the fire. There is a definite pressure drop between the water in the bottom of the drum and the water in the immediately adjacent part of the downcomer tube, to give the water its velocity in the downcomer. This pressure drop is not regained anywhere. The kinetic energy of the water is finally dissipated, along with the kinetic energy of the steam, in forming eddies of steam in the steam drum. (3) It must overcome the frictional resistance to flow of the water and steam. It will not affect results appreciably if the friction loss at the bend at the bottom of the "U" is neglected. (4) It must provide the necessary pressure drop to produce the acceleration as the water evaporates into steam. This has been conveniently termed "acceleration head."

It must be repeated that a large part of the kinetic energy, or the velocity head, of steam, is not derived from the available head of water, but is part of the heat energy obtained from the fire. Thus, to calculate the head causing flow, and the resistance to flow, the rate of heat absorption and the water velocity must be known. Equilibrium will be attained if the available head equals the sum of the four requirements; entrance loss, velocity head of water, friction head, and acceleration head.

To show how the head available is utilised in these four ways, a numerical example has been calculated for the standard U-tube shown in Fig. 1. The water velocity is 5·3 ft. per second and the head required to produce that velocity is 6·2 ft. This total is accounted for by an entrance loss of 0·22 ft.; velocity head of water of 0·44 ft.; total friction head of 3·64 ft.; and acceleration head of 1·9 ft. Since the dryness at the top of the upcomer is 0·0278, or $\frac{1}{36}$, this is, therefore, what is popularly termed a "36 times round" boiler, that is, any pound of water has to circulate 36 times round the tube before it is completely evaporated. This shows more than ample flow to prevent any danger of overheating the tubes, even though only natural head has been available, and though the rate of heat absorption has been quite high.

Having derived a method of computing the flow in the U-tube, for a definite rate of latent heat absorption over a definite length of tube, an analysis was made of the operation of the U-tube boiler for other rates of heating, for other pressures, and for alternative positions of the point of evaporation. Investigating first the effect of varying the rate of heat absorption, it is assumed that the point of evaporation remains on the upcomer at a point 10 ft. below the drum. The first notable point is that the velocity of the water supply to the tube has a maximum value of about 5·4 ft. per second, when the rate of heat absorption is 45,000 B.Th.U. per square foot per hour. The velocity falls off slightly with increased heating, though even with three times the heat the velocity is still 4·1 ft. per second. With lesser heat the velocity is less, but this is not important.

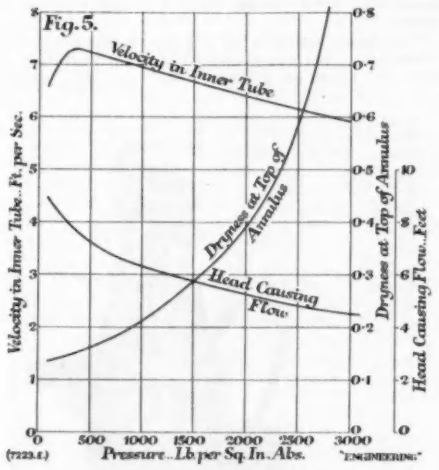


Fig. 5.
Velocity in Inner Tube
Dryness at Top of Annulus
Head Causing Flow
Velocity in Inner Tube.-Ft. per Sec.
Dryness at Top of Annulus
Head Causing Flow.-Feet
0 1 2 3 4 5 6 7
0 0·1 0·2 0·3 0·4 0·5 0·6 0·7 0·8
0 2 4 6 8 10
0 500 1000 1500 2000 2500 3000
Pressure.-Lb per Sq. In.-Abs.
(7223.E.)
"ENGINEERING"

Tube, 1¼ in. outside diameter; inner tube, ½ in. diameter; length, 12 ft. 6 in. Rate of absorption of latent heat, 50,000 B.Th.U. per square foot per hour.

A second analysis of the U-tube boiler was made by calculating the flow for various pressures, assuming the rate of heat absorption to be constant, and the position of the point of evaporation to be steady. Values have been calculated, for pressures between 15 lb. and 3,000 lb. per square inch abs. The rate of heat absorption over that part of the tube absorbing latent heat is taken as 50,000 B.Th.U. per square foot per hour. The head diminishes throughout the range of pressures, due mainly to the decreased difference of density between water and steam at high pressures. The velocity of water in the downcomer is a maximum at 300 lb. per square inch. At higher pressures, the velocity falls off slightly, though not so rapidly as the head causing flow, since the acceleration head and the extra friction due to increased speed of steam are less for high pressures than for low pressures. It would appear that the tube would give satisfactory operation, even up to pressures of 3,000 lb. per square inch.

A third analysis of the U-tube boiler is made to find how the water velocity varies, if the point of evaporation is located at different parts of the tube. Values have been calculated for rates of heat absorption of 10,000, 50,000, and 100,000 B.Th.U. per square foot per hour, and for points of evaporation 24, 20, 15, 12½, 10, 5, and 0 ft. from the top of the downcomer tube. The resulting graphs enable the stability of the flow to be examined, and show, among other things, that for high rates of heating, it is dangerous to have a heated downcomer; the circulation will be faulty. To ensure that this does not take place, it is advisable that the downcomer tube should not be heated at all. There are other reasons for not heating the downcomer, but results obtained with the demonstration boiler may be mentioned here. For this experiment the central tube B was plugged up and not used. With tube A only being heated, circulation is absolutely satisfactory. If heat is now applied gently to tube C, bubbles of steam are seen to form on the inner tube, and to be dragged down by the current of water. If greater heat is applied the bubbles increase until their buoyancy is sufficient to stop the flow. A very slight further increase is enough to upset the flow completely, with violent surgings in both tubes. At times the inner tube is seen to be quite dry. Though only rough measurements were possible, this interruption was found to take place if the downcomer is heated even to one-sixth of the amount by which the upcomer is heated. This figure is of the same order as the ratio between rates of heating of fire row and back tubes of an inclined tube boiler.

Some Modifications of the Standard U-Tube Boiler.—It has been shown that the circulation in the standard single U-tube is perfectly satisfactory for a very wide range of pressures and rates of heating, with only one proviso, namely, that the downcomer should not be heated. Several modifications of the standard U-tube will now be considered. Existing boilers consist of various arrangements of drums, headers, and tubes, in which a simultaneous solution of the problems of circulation, heating, and construction is aimed at by trial and error. (1) If a U-tube boiler consists of a drum with several U-tubes in parallel attached to it, and if these tubes are heated at different rates, the position of the point of evaporation will vary in each. The temperature of the water in the drum will be uniform. Hence the water has to travel farther in some tubes, which are less intensely heated, than in others, before obtaining all its sensible heat. The effect will be to raise the point of evaporation higher on the upcomer for the lesser heated tubes, and to lower it on the intensely heated tubes. The danger of interrupted circulation would be aggravated when a boiler consists of several U-tubes in parallel, heated at different rates. In the intensely heated tubes, the point of evaporation might easily be in the downcomer, with consequent instability.

(2) As regards discharge of steam into the steam drum below the water level, in all discussions hitherto, this point has been avoided by stipulating that the discharge should be above the water level. There are practical objections to a drowned discharge, in that the current of steam passing upwards entrains particles of water, and becomes wetter. The resistance to the flow of steam must be greater if it rises through water than if it rises in a dry tube, owing to the momentum given to these entrained drops. The flow in the tube will be adversely affected. Moreover, a violent turbulence is set up in the drum, causing steam and water to mix up into a froth. This has an important effect on the supply of water to the downcomer, since the reduced density reduces the weight of water flowing, and increases the dryness of the steam in the upcomer. These effects were clearly shown in the demonstration boiler. With a drowned discharge to the upcomer, turbulence in the top drum was excessive; with a dry discharge there was no turbulence.

If both upcomer and downcomer have a drowned discharge, there will be a flood of water in both tubes. The explosive forces of evaporation will be doubled in intensity, and any forces tending towards resumption of a steady flow will have the greater disturbing forces to overcome. This state of affairs was frequently observed in the demonstration boiler. Once circulation was upset by overheating the downcomer, it could be restarted only by shutting off heat to the downcomer completely, and by making a fresh start to the experiment.

(3) By replacing the U-bend at the bottom of the U-tube by a drum, though still retaining only the single downcomer and the single upcomer, the resistance to flow is increased. The kinetic energy of the water in the downcomer is dissipated in eddies in the lower drum, and at the entrance to the upcomer tube there must be a pressure drop to restore this kinetic energy and to overcome the loss at entrance. If steam is being generated in the downcomer, the kinetic energy of the steam is destroyed in the same way. Although the kinetic energy of this steam, when it was actually in the downcomer, was derived mainly from the fire, and not from the head of water, the replacement of this kinetic energy, when the steam commences to flow up the upcomer, will entail a pressure drop.

(4) If a bottom drum is used but the tubes are inclined, say, at 45 deg., the head causing flow is reduced, although the resistances are the same as before. When the point of evaporation is in the downcomer, there is an increased tendency towards instability. The head of water in the drum, above the entrance to the downcomer, is greatly reduced in this design, so that the liability of the contents of the tube to be blown out is increased. If the steam discharges below water level, causing the water and steam in the drum to be in violent turbulence, the adverse effect on the supply of water to the downcomer would be greatly increased by the nearness of the downcomer entrance to the water level.

(5) With an upper and lower drum, connected by a downcomer and an upcomer, together with a third tube, which may or may not be continued up above water level, faulty circulation will result and heating the downcomers may accentuate the conditions under which stagnation may exist. The conditions described in this section apply whether the drums are vertically above each other, or if the tubes are inclined, or even if they are nearly horizontal, joining headers at each end. The arrangement of water-wall tubes in parallel

* The calculations in the paper have been omitted from considerations of space.—ED., E.

between horizontal headers is another example. By arranging tubes in parallel, bad circulation results, with violent surges and possible stagnation. Stagnation in any tube immediately permits overheating of the tube to take place. The most effective method of obviating this is to provide each steaming tube with its own downcomer, as in the standard U-tube, to ensure that the head available will not be unequally divided. These conditions were reproduced in the demonstration boiler (Fig. 2). With heat on A, but no heat on B or C, circulation is satisfactory.

(6) In the so-called "high head" boilers, the apparent purpose of providing a high head is to increase the length of tube containing steam of maximum dryness and minimum density, counterbalanced by an equal length of downcomer tube containing water. The increase in head should increase the velocity of flow in the tube, and hence improve the circulation. On calculation, however, the benefit appears to be very much less than might be expected. The adoption of high heads does not of itself increase the circulation appreciably, unless provision is made to reduce the friction in the extra connecting pipes. The same considerations apply to water-wall tubes.

(7) In the usual types of forced-circulation boilers, recently introduced to ensure better circulation, it is usual to employ very long tubes, in which the contents may be either completely evaporated, or evaporated to a fairly high dryness fraction. The chief merit claimed for such boilers is that circulation is positive. Yet the U-tube boiler is equally, indeed more, dependable with natural circulation and without accessory pumping equipment. Forced circulation permits the tubes to be arranged in any desired way, but there are difficulties of cleaning, inspection, and of removal and replacement.

(8) The "Field" tube was invented about 100 years ago by Perkins, and improved by Field some 80 years ago. An improved arrangement of the Perkins-Field tube is shown diagrammatically in Fig. 4. A single water and steam drum is provided. The heating element consists of an outer tube projecting radially from the drum, at some convenient angle of inclination, and closed at its lower end. The steam formed in this tube is conveyed above the water level in the drum through a special compartment. An inner tube, leading from the water section of the drum, conveys the water to the lower end of the outer tube. In a boiler consisting of several such tubes attached to the same drum, every tube forms an individual heating unit. The performance of this tube may be calculated in the same way as for the simple U-tube. Values of velocity in the inner tube, dryness fraction at the top of the annulus, and the head causing flow, are plotted in Fig. 5, for various pressures from 100 lb. to 3,000 lb. per square inch, with a heat absorption rate of 50,000 B.Th.U. per square foot per hour. This and other graphs show that this tube gives good results even when the heat is extremely intense.

A boiler using these tubes has been designed for an electric power station, using low-grade fuel, and producing 36,000 lb. to 45,000 lb. of steam per hour at 400 lb. per square inch pressure and 725 deg. F., from feed water at 280 deg. F. There is a single drum at the top, supported by trestles external to the combustion chamber. The steaming tubes are arranged in a bank subjected to both radiant and convectional heating, and as water-wall tubes subjected to radiant heat only. Each tube has only one expanded tube joint, namely, that at its upper end, and each tube is straight and easily inspected, externally and internally, and can be replaced without disturbing any others. A Lewis boiler* designed on these principles has been in operation for the last four years, giving excellent results. No trouble with circulation or tube joints has been experienced, though the rate of firing on occasions exceeded 1 lb. of fuel oil per square foot of heating surface. Annual inspections have revealed no tube distortions or distress, also that all interior tubes, etc., which have three times been drained and withdrawn, and then replaced, are as clean and sound as when they were installed. The boiler has no superheater or economiser, yet yields efficiencies of 66 per cent. and 70 per cent., respectively, at the higher and lower calorific values of the fuel. It raises steam at 200 lb. per square inch pressure within 15 minutes. The feed water is of 16 deg. hardness, reduced to 2 deg. or 3 deg. by a hot lime-soda softener. Concentration is kept low by a continuous blowdown, the make-up being 100 per cent. Repeated samples of water tapped from the bottom of the U-tubes have proved that no deposit remains there. A further recently completed design† is a portable boiler for Air Raid Precautions duties. This boiler, having a capacity of 6,000 lb. of steam per hour at 185 lb. per square inch pressure when hand-fired with coal under very low natural draught, weighs less than 10 tons, and may be towed behind any commercial vehicle or tractor.

* See Engineering, vol. 139, page 453 (1935).

† See Engineering, vol. 148, page 90 (1939).

OIL-GROOVE CUTTING MACHINE.

The machine shown in the accompanying illustration and known as the Wicaco Continuous Oil Groover, is designed for cutting oil ways or oil grooves either internally, as in sleeves or bearings, or externally, on axles, shafts and spindles. Grooves can be cut in bores ranging from $\frac{1}{4}$ in. to $4\frac{1}{2}$ in. in diameter, the latter dimension being also the limit for external grooving when the standard three-jaw chuck of the machine is used, a somewhat larger diameter being possible by employing a face plate. The maximum depth of the grooves is $\frac{7}{32}$ in., and their maximum width is $\frac{3}{8}$ in. As is well known, oil grooves on cylindrical surfaces have usually a helical contour; they may, indeed, be plain helices, either right-handed or left-handed, but combinations of the two are also commonly used, *e.g.*, closed loops and figures of eight. In any case a helical contour involves simultaneous circumferential motion of the cutting tool and its traverse in a direction parallel to the axis of the cylindrical surface being cut; in other words, a motion resembling screw-cutting with a greatly exaggerated pitch.

The drive, which is by a $\frac{3}{4}$-h.p. motor running at 1,200 r.p.m., is through change gears for providing the different types of groove. The gears are selected

according to the desired speed of the cutter and the ratio between the strokes and revolutions of the cutter spindle. Thus, if it be desired to cut a single loop, change gears that would give one revolution of the spindle to one stroke are required, while, for a figure-eight groove, gears giving two revolutions to one stroke are necessary. Five different cutter speeds and 11 different types of groove may be cut with the standard set of gears, and with this set it is also possible to cut a right-hand or a left-hand helical groove up to 1·5 revolutions per stroke, and, by means of a set of auxiliary change gears, ratios of from one revolution to eight revolutions per stroke are possible. The operation of gear changing for even the most difficult type of groove is stated not to occupy more than 10 minutes. The machine in its simplest set-up cuts a continuous groove of either a right-hand or left-hand lead. If a groove of only one lead, or a groove of two leads not connected at the ends, *e.g.*, an "X" groove is required, a cam is used to withdraw the cutter from the work so that it can cross the space not to be grooved. The normal equipment includes two cams, which serve for all standard types of groove, but extra cams can be provided to cut any form of special groove.

The work, when a plain cylinder such as a bush, within the maximum dimensions, is held in the three-jaw scroll-type chuck seen at the top of the machine. The chuck is operated by a lever handle actuating a pinion and gear and is carried on three posts, one of which is screwed to take an elevating and lowering nut. An adjustable arm on another of the posts carries a stop for locating the work. Work of such a size and shape that it cannot be held in the standard chuck is secured to a face plate attached to the chuck base. A half-bearing bush is held in an air-operated vice, the jaws of which are formed so that it locates itself accurately as the jaws close. Work which has to be slotted or have an elliptical groove cut in, is held in a screw fixture. The spindle does not rotate in these operations but reciprocates only. The work is fed against the tool and a cam is employed to relieve the tool on the up stroke. An indexing fixture is employed for work having two straight grooves opposite to one another or at an angle, circumferentially, to one another. The above comments apply to internal grooving, etc. For the external grooving of shafts the work is usually held in the standard chuck, provided the ungrooved length is sufficient to afford a secure hold. The cutter is carried in a hollow tool post which surrounds the work and which has holes at the bottom for the escape of swarf. Certain arbors and so forth are used for the external grooving of bushes, but without enumerating all the provisions made it may be said that the machine is very flexible as regards the work that can be done on it.

The stroke of the spindle, which is determined by the length of the groove, is adjustable in steps of $\frac{1}{8}$ in., or, if required, of $\frac{1}{16}$ in., and the capacity is from zero to 7 in. Work with grooves longer than 7 in. can be dealt with by reversing it and completing the cut by a second operation. The machine is claimed to present a number of advantages over the older types of machine. Thus, the adoption of a vertical spindle and stationary chuck enables work to be changed without having to stop the motor, a characteristic which has largely improved the output when the machine is used for quantity production. It is stated that as many as 500 workpieces per hour can be produced, even by unskilled labour. The tool feed depth is automatically controlled, the feed lever returning by itself to the neutral position when the correct depth of cut has been reached. The construction is on modern machine-tool lines, cast steel being used in all parts subject to heavy stress. The bearings are of phosphor bronze and the shafting gears of 0·4 to 0·5 carbon steel. The spindle is 3 in. in diameter and is made of 0·5 carbon open-hearth steel, heat treated and ground. All moving parts are lubricated either by individual oil cups or from one or two main reservoirs. The machine is manufactured by Messrs. The Vicaco Machine Corporation, Philadelphia, Pennsylvania, U.S.A., and is distributed in Great Britain by Messrs. E. H. Jones (Machine Tools), Limited, Edgware-road, The Hyde, London, N.W.9.

EXPERIENCES WITH HIGH-TEMPERATURE HIGH-PRESSURE STATIONS.

(*Concluded from page* 232).

We give below the final section of our abstracts of the papers, dealing with power-station operation, presented at the meeting of the American Society of Mechanical Engineers held in Philadelphia in December, 1939.

Logan Operating Experience.

By Philip Sporn.

Before beginning a review of the approximately two years of operating experience at the Logan Station of the Appalachian Electric Power Company, a brief description of the major equipment installed in 1937 will be of help as a background. The superposed extension consists of a 40,000-kW, 3,600-r.p.m. water- and hydrogen-cooled generator supplied with steam at 1,250 lb. per square inch, 925 deg. F., from a single boiler of 1,000,000 lb. per hour capacity and exhausting at 200 lb. per square inch, 510 deg. F., to five low-pressure turbines totalling 50,400 kW. At the time of its purchase in 1935, the 40,000-kW turbo-generator was the largest-capacity 3,600-r.p.m. topping unit that could be proposed, and the first hydrogen-cooled generator placed on order. It is also, so far as is known, the only water-cooled generator stator. The boiler is still the largest built to date.

Initial operation of the high-pressure boiler was started in October, 1937, and trial operation of the turbine, November 2, 1937. Since the starting date until August, 1939, comprising 15,638 hours of elapsed time, the high-pressure section of the plant was available 8,956 hours, or 57·3 per cent. of the time, while the service hours were 8,750, or 56 per cent. of the time. With a gross generation of 255,527,000 kWh, the capacity factor for this period has been 40·8 per cent. The availability of the high-pressure turbine alone was 86·4 per cent., and the service hours 56 per cent. of the elapsed time. The single high-pressure boiler, which is used for the low-pressure section of the plant through the pressure-reducing and de-superheating system when not supplying the topping turbine, had service hours equal to availability amounting to 71·8 per cent. of the period. Since July, 1938, when the last major turbine difficulty was remedied, the record is more pleasant to report. The availability of the high-pressure section of the plant increased to

81·5 per cent., the service hours to 80·2 per cent., and the capacity factor to 61·8 per cent. For the turbine only the availability at 97·2 per cent. and the service hours at 80·2 per cent. have been quite satisfactory. The high-pressure boiler performance is encouraging, with availability and service hours increasing to 84·7 per cent. in this 13-month period.

During the 13-month period, the station heat rate of 14,400 B.T.U. per kilowatt-hour compares favourably with the design expectations, remembering that a serious shortage of circulating water in the summer months, necessitating spray nozzles and recirculation, is an uncontrollable influence on overall plant economy. Under such conditions, the condenser pressure attains as high as 3·4 in. Hg, and the additional large auxiliary power consumption to operate the spray-pond pumps amounts to 8 per cent. of full-load generation.

Although the high-pressure turbine is rated at 40,000 kW, and the five low-pressure turbines aggregate 50,400 kW, making a station rated at 90,400 kW, much higher loads have been consistently possible because of hydrogen cooling of the topping unit and nozzle changes on the low-pressure units. Under favourable winter conditions, with ample circulating water, a gross station load of 103,000 kW has been attained, involving 48,500 kW on the 40,000-kW topping unit supplied with 1,000,000 lb. per hour of steam from the single high-pressure boiler. This high load represents a reserve capacity available of 12,600 kW, or 14 per cent.

Operating procedure, as originally set up for this station at the time of initial operation late in 1937, has proved to be entirely satisfactory and no major modifications have as yet been found necessary. Basically, the system of starting and stopping is one in which the low-pressure boilers, the low-pressure turbines, the high-pressure boiler, and the topping turbine are treated as separate divisions, each of which is operated separately but in sequence. Whenever the high-pressure boiler is out of service at least two of the low-pressure boilers and two of the five low-pressure turbines are operated. The desired load on these units is maintained by backing down on the low-pressure boilers while steam flow is increased through the reducing valve as the high-pressure boiler is started and loaded. The high-pressure boiler could not be started without at least one of the low-pressure boilers in service, because the induced-draught fans are turbine-driven. Then the topping turbine is warmed through a manually-operated atmospheric exhaust. When ready, the topping turbine under control of the speed governor is synchronised, then put under control of the back-pressure governor, and loaded while flow through the reducing station decreases. The reverse order is followed when taking the high-pressure equipment off the line. Under running conditions, the reducing valves are closed, the load is varied on the low-pressure turbines which, in turn, controls the steam flow and load on the topping unit through the back-pressure regulator on the topping turbine.

There have been several interesting experiences which indicate the flexibility of the station. On one occasion a test trip-out of 15,000 kW and an accidental trip-out of 36,000 kW of low-pressure unit capacity created no disturbance beyond control of the boiler operator and without popping of safety valves. There was an occasion when one of the induced-draught fans was lost and another when a forced-draught fan was lost, both times with full load on the high-pressure boiler, but recovery to stable operation was accomplished without difficulty. Any system disturbance affects the load less on the topping unit than on the low-pressure units.

A most interesting incident occurred once when the entire station load was lost. The pressure in the 200-lb. steam header, supplying the low-pressure units, dropped to as low as 60 lb., but this was sufficient to keep in operation the turbine-driven induced-draught fans on the high-pressure boiler supplied from this header, without firing the low-pressure boilers.

High-Pressure Turbo-Generator.—The major outages on the high-pressure turbine have resulted from failure on two occasions of the first-stage shroud band. With the second shroud-band failure, the turbine manufacturer gave proper consideration to the extreme combinations of stress to which the first-stage blading is subjected, involving intermittent stress from partial peripheral admission and stress from centrifugal force coupled with high-temperature effect. Since the second repair was completed and the turbine placed on the line on July 15, 1938, it is gratifying to be able to report that no further trouble has resulted to date from the first-stage shroud band. The only other serious difficulty occurred when the thrust bearing let go, but since its repair there has been no recurrence.

Overheating of blades in the topping turbine, caused from motoring of its generator with insufficient steam flow, when low-pressure units have tripped out, is prevented at Logan by a special reverse-power relay. The scheme consists of a sensitive reverse-power relay calibrated to operate on power component only and to close its contacts to trip the generator off the line in case the power flow is from the 'bus bars into the generator, with a magnitude of $\frac{1}{2}$ per cent. of the kilowatt rating of the generator after a time of 1 minute. In addition to this reverse-power relay, a timing relay is provided to give the desired time of 1 minute. A single current transformer is employed with a ratio of approximately full-load rating of the generator to give 5-ampere secondary current. Furthermore, a lock-out, single-phase, reverse-power relay is provided to make the above sensitive reverse-power relay inoperative, provided the generator is supplying power to the 'bus bars of an amount equal to, or greater than, 40 per cent. of its kilowatt rating. The installation of this lockout relay is provided to insure that the generator will not trip off the line unnecessarily due to improper operation of the sensitive reverse-power relay on surges or otherwise. In addition, an alarm circuit is provided to operate at the instant the generator starts motoring, so as to inform the operator that the generator is motoring and permit him to correct conditions within the period of 1 minute before tripping occurs, if possible. During the last year there have been two occasions when the low-pressure units have tripped out from failure of the group excitation for these units. On both occasions the high-pressure unit was prevented from motoring by the successful functioning of the special reverse-power relay.

When the topping turbine is being shut down, the rise in exhaust-steam temperature is negligible before the exhaust is opened to the atmosphere, but in bringing the turbine on the line after a short shutdown period the stored heat raises the exhaust steam approximately 175 deg. F. until loaded and under control of the governor. There have been no vibration problems with the topping turbine and the use of vibration and eccentricity recorders has proved helpful during starting periods.

The hydrogen-cooled generator has functioned most gratifyingly, even under capacity load with the adverse condition of high cooling-water temperature. Although this generator is designed for a gas pressure of 15 lb. per square inch and has had test runs at this pressure, during which the shaft-sealing and gas consumption were satisfactory and lower temperature of windings realised, day-by-day operation has been confined to a pressure of 0·5 lb. per square inch. Even with cooling water at 90 deg. F., a higher gas pressure was not needed to effect proper cooling of the windings. Hydrogen purity is easily maintained at 99 per cent. to 100 per cent., and gas consumption, averaging less than 40 cub. ft. per day, has been costing less than 300 dols. per year.

Regarding the pad-cooling arrangement for direct water cooling of the stator, outside of the original difficulty with the removal of air from the system, satisfactory performance has been obtained. There have been no signs of water leakage either in the pads or in the piping of the system. It has not been necessary at any time to remove and replace the condensate used as make-up for this pad-liquid system. Two heat exchanges are provided for the cooling of the pad liquid, both of which are used during the warmer months, but only one of which is needed during most of the year.

High-Pressure Boiler.—The 1,000,000-lb. per hour, dry-bottom, pulverised-fuel boiler, has been subject to more outage than the turbine. Ash-screen tube failures, resulting from impaired circulation and excessive heat input, required replacement. Smaller-diameter tubes having spiral circulating strips and an increased slope were substituted and burner angles adjusted with satisfactory results.

West Virginia bituminous coal from four different seams, with ash-fusion temperatures ranging from 2,350 deg. to 2,700 deg. F., has been burned without difficulty. Slagging has not been serious and cleaning of boiler tubes by soot blowers and lancing has been easily accomplished. Load swings of 10,000 lb. to 15,000 lb. per hour are readily handled and, on occasion, it has been possible to drop load from 900,000 lb. to 540,000 lb. per hour momentarily. Steam temperature has been controllable within the prescribed range with the remotely-operated by-pass dampers. With tangential firing, a minimum boiler load of 300,000 lb. per hour can be attained without loss of flame stability. However, it is interesting to note that, with a fuel combination of gas and coal, a load of 175,000 lb. per hour has been carried successfully for a 2-hour period. Four auxiliary natural-gas burners are used for starting with the aid of a kerosene torch and together are capable of carrying a boiler load of 50,000 lb. per hour. The four Hardinge mills, each of 15 tons per hour capacity, have been rendering satisfactory service with a power input of 16 kW each at full capacity. To date, these four pulverisers have handled a total of over 350,000 tons of coal. Experience indicates that exhauster blades made of boiler plate require replacement after a mill has handled 35,000 tons, and the wear on the ball charge amounts to 0·086 lb. per ton of coal. The two Ljungstrom air heaters, when cleaned once each shift with steam soot blowers, have maintained their capacity and have exhibited no tendency to fouling. However, the exit flue-gas temperature, leaving the air heaters, remains about 30 deg. or 40 deg. F. higher than the manufacturer's performance guarantee.

Feed-water make-up is supplied from an evaporator fed by coagulated river water in which temporary hardness usually predominates, forming a scale in the evaporator not readily susceptible to cracking. To offset this, approximately 0·2 parts per million of tannin is added to the evaporator feed for 1 part per million of hardness. Total dissolved solids in the vapour leaving the evaporator is confined to 2 parts per million or less. A pressure-type de-aerator, located midway in the feed-water heating circuit, using exhaust steam from the turbine-driven induced-draught fans, has consistently maintained the dissolved oxygen of the feedwater at 0·005 cc. per litre or less. Scavenging of final oxygen is obtained by continuous feeding of ferrous sulphate and caustic soda at the de-aerator outlet in proportion to the dissolved oxygen in the feedwater. At no time does the boiler water show the presence of ferrous iron. Orthophosphates and caustic are fed in shots into the feed-water at the discharge side of the regulator for maintaining a *p*H value of 9·6 and a phosphate concentration of 10 to 25 parts per million as PO_4. Boiler water total solids range between 100 and 250 parts per million.

The saturated steam from the boiler has a specific conductivity averaging from 0·5 to 0·7 microhmos. Even so, some fouling of turbine blades, as evidenced by increasing first-stage pressure, has been experienced after long periods of continued operation, suspected to be attributable to iron from the oxygen scavenger, not detectable by conductivity determinations because of being too slightly ionised. Only recently the oxygen-scavenger feed was temporarily discontinued to determine the effect on first-stage pressure drop. Fortunately, the deposit on the turbine blades seems to be removed or greatly reduced following a turbine shut-down. The only reason assignable to this is that the condensation on the blading during the subsequent warming-up period washes off the deposit.

Boiler Feed Pumps.—Three identical 3,600-r.p.m. feed pumps are installed, one of which is motor-driven and two turbine-driven with the exhaust steam absorbed in the feed-water heating cycle. Ordinarily, the turbine-driven pumps are used, with the motor-driven as stand-by. These pumps have horizontally-split cases and handle water at 350 deg. to 390 deg. F. Their performance has been satisfactory in every way except for failure of ring gaskets involved with the removable head at the discharge end of the pump where the balancing discs are located. Apparently, it is a question of slightly warped castings and selection of suitable gasket material.

Reducing Valves and De-superheaters.—The two steam reducing valves for supplying the low-pressure section of the plant from the high-pressure boiler have been practically free of vibration and noise since initial changes were carried out. When the station is operating normally with exhaust from the topping unit supplying the low-pressure units, motor-operated shut-off valves ahead of the reducing valves are kept closed. This is believed to be favourable to the life of the reducing valves. The automatic de-superheating equipment, though somewhat complex, has functioned satisfactorily.

Heaters.—In the feed-water heating cycle, there are no heaters on the discharge side of the boiler-feed pumps. Following the de-aerator on the suction side of the feed pumps are two vertical surface heaters of the floating-head type, both handling water at 450 lb. per square inch and using steam at 100 lb. and 200 lb. per square inch, respectively. Admiralty tubes in the 100-lb. heater and arsenical-copper tubes in the 200-lb. heater have both functioned satisfactorily thus far, without leakage or tube dirtiness. After some experience with various head gaskets, the toroidal type was definitely unsatisfactory, but copper and corrugated Monel have proved to be much superior. Drain sub-coolers built into heaters are not used at Logan. However, a separate drain cooler, used in conjunction with the 100-lb. heater, has performed up to expectations, with control of the drains on the outlet side so that no flashing can occur in drain piping between the drain cooler and the heater being drained.

Electrical Features.—The entire output of the Logan topping unit, as well as substantially all that of the five low-pressure machines, is taken care of by a single, 4-winding, 100,000-kVA transformer bank with windings operating at 4,000, 11,000, 44,000 and 132,000 volts. Further, the larger station auxiliaries are fed through a newly-developed magnetic air-type circuit-breaker switchboard. Both of these large and/or new developments have worked out most satisfactorily. No trouble has been experienced with the load-distribution or regulating characteristics of the multi-winding transformer. The air breakers showed their rating capability in an elaborate series of acceptance tests and have functioned with a complete absence of difficulty.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the communicators are given in italics.

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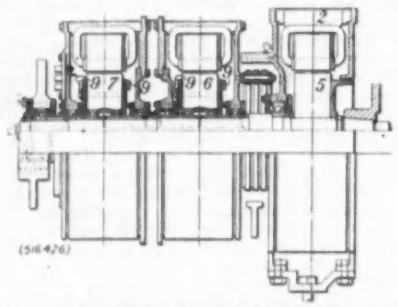
ELECTRICAL APPARATUS.

516,426. Dynamic Balance Tester. The General Electric Company, Limited, of London, and A. B. Cape, of Witton. (1 *Fig.*) May 23, 1938.—The tester is primarily designed for balancing the rotors of alternators or electric motors. The balancing head is arranged to be coupled to a rotor under test. On the shaft are mounted the rotors of a polyphase alternator 2 and two polyphase synchronous motors. The rotors 5, 6 and 7 of these machines are permanent magnets, the rotor 5 being keyed to the shaft and the rotors 6 and 7 rotating on it on roller bearings. Each of the rotors 6 and 7 is provided with out-of-balance weights 9, which are adjustable in position. The stator of the alternator 2 is fixed, while the stators of the motors can each be rotated by



rocking gear. All the stator windings are connected in parallel. In operation, the rotors 6 and 7 of the synchronous motors follow up any movement of their respective stators, so that the displacement of the rotor 6 or 7 relative to the rotor 5 of the alternator will be exactly equal to the displacement of the respective stators. Hence a movement of the stators causes a corresponding displacement of the weights 9 in relation to the rotor under test. It is therefore possible to vary the effect of the weights both in magnitude and direction. When the angular positions and magnitudes of the weights necessary to balance the rotor under test have been determined balance weights are correspondingly fixed to it. (*Accepted January* 2, 1940.)

GUNS AND EXPLOSIVES.

515,992. Aircraft-Gun Mounting. Boulton Paul Aircraft, Limited, of Wolverhampton, and J. D. North, of Bridgnorth. (9 *Figs.*) March 24, 1936.—The invention is a gun mounting for aircraft which substantially increases the field of fire. The figures show the method of mounting guns on a large aircraft. The body has an extension 15, projecting behind the tail plane, elevators and rudders. This extension carries the gunner's cabin 16, and two projecting members 17 (Fig. 2), each of which carries at its outboard end a turntable 18 on which is mounted an arm 19. At the end of each arm 19 is a further turntable 20, the axis of which is horizontal, and upon each of the two turntables 20 is a gun carrier 11. Rotation of the gun mountings on the turntables 20 permits the guns of both mountings to fire over an arc of about 300 deg. in elevation, which is limited in the upward and forward direction by the rear edge of the elevator, and in a downward and forward direction only by parts of the aeroplane forward of the tail, such as the wings. The turntables 18 allow the guns to be fired over an arc of at least 180 deg. in azimuth, and the guns on both mountings can fire at a target on either side of the aeroplane, the guns on the side remote from the target firing past the end of the body. The members supporting the gun mountings are hollow, so that the control gear for the guns may pass through them. (*Accepted September* 16, 1937, as secret patent; *published December* 6, 1939.)

Fig.1.

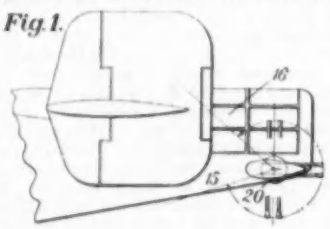
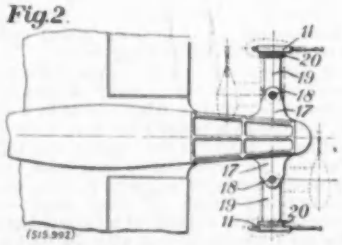
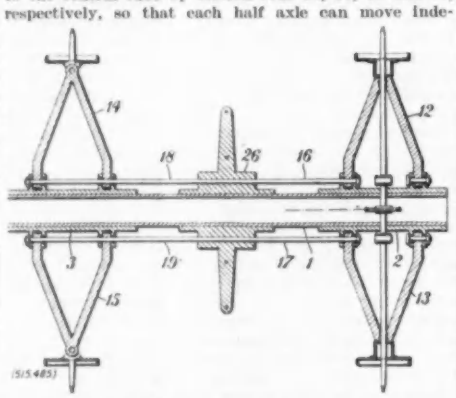


Fig.2.



MOTOR ROAD VEHICLES.

515,485. Motor Car. Works Development Company, Limited, of London, and J. Ehrlich, of London. (1 *Fig.*) June 1, 1938.—The car is designed for simplicity of construction and can be mass-produced at a relatively low cost. A single spine tube 1 constitutes the main frame supporting the engine and body. Sleeves 2 and 3 are secured around the tube and carry bifurcated bearing lugs. Triangular axle units 12, 13, 14, 15 are attached to the central tube by torsion rods 16, 17, 18 and 19, respectively, so that each half axle can move independently of the others. The axle units 14 and 15 for the front wheels are duplicated and hinged to the main tube one above the other, so as to maintain parallelism between the wheels. Mid-way between the front and rear axle units is a platform 26, which encircles the tube and is formed of two halves bolted together. The rods 16, 18 and 17, 19 pass through squared holes formed partly in each half. The body is bolted to the platform and rests upon the axles through springs. The engine is mounted at the rear of the chassis immediately over the rear pair of axles, thus dispensing with a transmission shaft. A chain wheel common to both driving axles is mounted on a single drive shaft and is driven directly from the engine shaft. The connection to the driving axles is through universal joints of the rubber-disc type. The body is composed of tubular main-frame members to which the panelling is screwed. (*Accepted December* 6, 1939.)



516,434. The Associated Equipment Company, Limited, of Southall, and G. J. Rackham, of Bourne End. Trolley-'bus. (6 *Figs.*) June 21, 1938.—The invention is a trolley-'bus frame in which the elimination of body sills enables a deeper section frame to be used and produces a lighter construction. The underframe for a six-wheeled trolley-'bus consists of two channel-section longitudinals 20 and 21, which extend from in front of the front axle to behind the rear axles. Cross-members 30, 31 and 32 connect the longitudinals at points between the front and rear axles corresponding to the positions of the side pillars of the body. The cross-members project beyond and are of approximately the same depth as the longitudinals. They are each formed in three parts, the central part lying between the longitudinals and the outer parts projecting on either side. These parts of the cross-members are connected together by plates which overlie the longitudinals and are integral with the central parts. The central portion 45 (Fig. 2) is of single channel section, but the outer portion 44 which projects beyond the longitudinal is of double channel section and is tapered towards its extremity. The top and bottom flanges of the central part are continued to form the plates 49 and 57. These plates are of generally triangular form and are riveted to the top flange of the longitudinal 20 and also to the top flange of the outer portion 44. The central part 45 has turned-over end flanges 61, riveted to the web of the longitudinal by rivets which also secure the flanges of the outer part 44 to it. The body-work pillars are attached by angle brackets riveted to pillar supports 68, which embrace the pillars. The upper and lower flanges of the outer portion 44 are horizontal and parallel to facilitate lateral adjustment between the cross-

Fig.1.

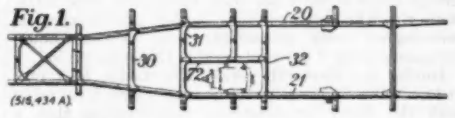
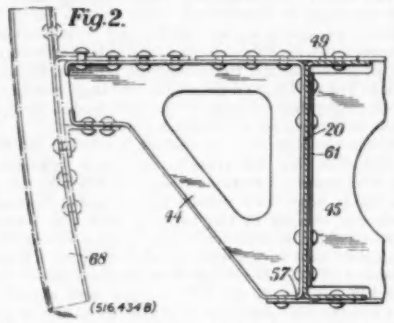
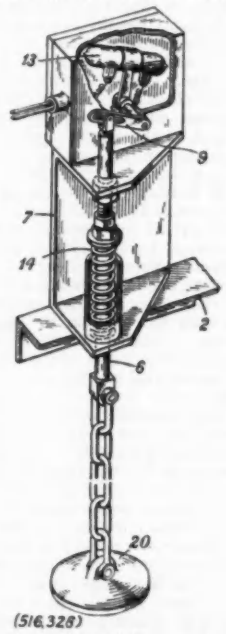


Fig.2.



member and the pillar before the parts are riveted. The cross-members 31 and 32 are connected by a short central member 72, between which and the outer longitudinal 21 the driving motor is slung. (*Accepted January* 2, 1940.)

MISCELLANEOUS.

516,328. Hopper Level Indicator. Elliott Brothers (London), Limited, of Lewisham, and D. C. Harben, of Bromley. (3 *Figs.*) July 19, 1938.—The indicator is particularly intended for use with granular substances, such as pulverised coal, grain, etc., and is designed to be free from the disadvantages of the flexible-diaphragm type of indicator, which is not always accurate when the material is of an agglomerative nature. A chain of considerable length is suspended by its upper end from a support 2 across the mouth of a pulverised-fuel hopper, so that its lower portion is covered when the hopper is full. The upper end of the chain is attached to the lower end of a vertical rod 6 sliding in a U-shaped bracket 7. The rod is connected to an arm 9 on a shaft to which is secured a clip carrying a mercury switch 13. A helical compression spring 14 around the rod compensates exactly for the weight of the chain and rod. The movement of the latter is limited by upper and lower stops. A disc 20 is suspended from the chain and has a conical upper surface. In order to prevent undue lateral displacement of the lower portion of the chain, steadying chains are connected between walls of the hopper and a link of the suspended chain. In operation, fuel supplied to the hopper embeds the lower portion of the chain and the disc 20 and drags them down against the spring 14. The mercury switch 13 is tipped to operate an electrical indicator. As the fuel level falls in the hopper, the frictional drag of the moving material maintains the switch 13 in the tilted position until the lower end of the chain is uncovered. Thereupon the spring 14 returns the rod and chain to the upper position and tips over the mercury switch to sound a warning or start up auxiliary apparatus for feeding fuel to the hopper. (*Accepted December* 29, 1939.)